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FINAL
PHASE I
REMEDIAL INVESTIGATION REPORT
(VOLUME I OF III)

CROYDON TCE SITE
BUCKS COUNTY, PENNSYLVANIA

AUGUST 1988
W.A. NO. 124-3LM7

AR300318

EBASCO SERVICES INCORPORATED

EBASCO

One Oxford Valley, Suite 414, Langhorne, PA 19047-1829. (215) 752-0212

August 19, 1988
RM/III/88-0427
Response Required

Mr. Jeffrey B Winegar
Environmental Protection Agency
Region III
841 Chestnut Street
Philadelphia, PA 19107

Subject: REM III PROGRAM - EPA CONTRACT NO. 68-01-7250
CROYDON TCE SITE, BUCKS COUNTY, PENNSYLVANIA
FINAL PHASE I REMEDIAL INVESTIGATION REPORT
AND PHASE II RI/FS WORK PLAN

Dear Mr. Winegar:

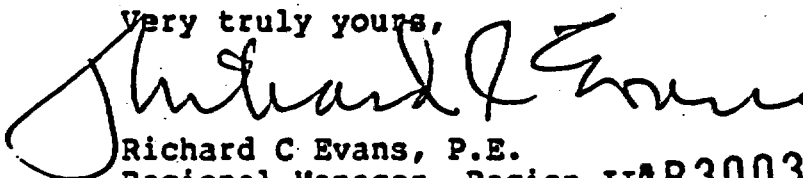
Enclosed are six (6) copies of the Final Phase I Remedial Investigation (RI) Report for the Croydon TCE Site. Volume I of this report consists of the RI text; Volumes II and III include the supporting appendices; the Phase II RI/FS Work Plan (Final) is included in Volume II of this report.

Comments submitted by EPA Region III for the Draft RI Report and Draft Phase II RI/FS Work Plan have been addressed in this report. Individual responses to each comment are given in Attachment A (RI comments) and Attachment B (Work Plan comments). The Final Phase II Field Operations Plan (FOP) will be forwarded to you following receipt of EPA comments.

The supporting REM III Team level of effort and cost estimates for conducting the Phase II scope of work have been revised and are being sent to you under separate cover. In accordance with the project schedule, we look forward toward your approval (and funding) of the Final RI Report and RI/FS Work Plan by September 23, 1988.

If you have any questions or comments regarding this report, please feel free to contact me or our Site Manager, Mr. Raymond P Wattras, at 412/788-1080.

Very truly yours,


Richard C. Evans, P.E.
Regional Manager, Region II

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RCE/RPW/kjb

Enclosures (8)

August 19, 1988
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Page 2

cc: S Del Re - EPA, Region III (w/o attachments)
M Yates - ZPMO (w/attachments)
M Amdurer - ZPMO (w/attachments)
S Missailidis - ZPMO (w/attachments)
L Johnson - NUS (w/attachments)
R Wattras - NUS (w/attachments)
P Krantz - EPA, Central Regional Laboratory
(w/attachments)
File: W.A. No. 124-3LM7 (621Y/553)
Daily

AR300320

AUGUST 1988

FINAL

PHASE I REMEDIAL INVESTIGATION REPORT

CROYDON TCE SITE
BUCKS COUNTY, PENNSYLVANIA

EPA WORK ASSIGNMENT NUMBER 124-3LM7
UNDER
CONTRACT NUMBER 68-01-7250

PREPARED BY:
NUS CORPORATION
PITTSBURGH, PENNSYLVANIA

APPROVED BY:
EBASCO SERVICES INCORPORATED
LANGHORNE, PENNSYLVANIA

PREPARED BY:

Raymond P Wattras

RAYMOND P WATTRAS
SITE MANAGER
NUS CORPORATION

APPROVED BY:

Richard C Evans

RICHARD C EVANS, PEH300321
REGIONAL MANAGER, REGION III
EBASCO SERVICES INCORPORATED

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EXECUTIVE SUMMARY

The Croydon TCE Site is located in Bristol Township, Bucks County, Pennsylvania, approximately 15 miles northeast of Philadelphia. Elevated levels of volatile organics, primarily trichloroethene (TCE), are present in groundwater and surface water, but the actual source(s) is unknown. Because the source of the contamination is unknown, a two-phased remedial investigation (RI) and feasibility study (FS) is being conducted. This Final RI Report presents the findings of the Phase I Field Investigation. The Final Phase II RI/FS Work Plan is presented in Appendix A of this report.

The Croydon TCE Site was identified by the United States Environmental Protection Agency (EPA) during the investigation of the Rohm & Haas Site, which borders part of the Croydon TCE Site (see Figure 1-1 in Section 1.0). Rohm & Haas Company, which operated an industrial landfill from 1952 to 1975, was undertaking an environmental study to determine whether the landfill was presenting a threat to human health or the environment. As part of this study, monitoring wells and residential wells north of the landfill area (i.e., upgradient with respect to groundwater flow) were contaminated with TCE and other volatile compounds (primarily constituents of TCE). Rohm & Haas concluded that a plume of contaminated groundwater was emanating from a source upgradient from its landfill and has migrated onto Rohm & Haas' property. Because many of the businesses in the Croydon area may also use products containing TCE, EPA determined that a separate RI/FS was required. In September 1985, the Croydon TCE Site was included on the EPA National Priorities List (NPL) and ranked 616th.

The community of Croydon encompasses the southernmost portion of Bristol Township. The area of which Croydon is composed is both residential and industrial. In addition to the Rohm & Haas facilities, several small- to large-scale manufacturing facilities are located in Croydon. Approximately 2,500 people reside in Croydon and the surrounding areas. Most of the homes in Croydon were built between 1940-1960, when manufacturing was at its peak and new businesses were being formed.

The manufacturing and commercial facilities are located in the eastern portion of Croydon, whereas the residential areas encompass the central and western portions of Croydon. Commercial businesses are primarily located along U.S. Route 13 and State Road, which run somewhat parallel before they intersect with Route 413. The area north of U.S. Route 13 is mostly residential. This area is known as Croydon Heights and Croydon Acres.

The geology of the Croydon TCE Site consists of unconsolidated sand, gravel, silt, and clay deposits overlying bedrock. Unconsolidated deposits within the Delaware River

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Valley consist of Upper Cretaceous sediments of the Raritan Formation and Quaternary age deposits, primarily Pleistocene (Wisconsin) age glacial outwash in the form of valley fill deposits, which are overlain by a thin veneer of recent alluvium. Total thickness of the unconsolidated deposits in well borings ranged from 29 to 69 feet in the study area and from 40 to 65 feet in the borings south of the study area (BCM, 1986a).

Bedrock underlying the unconsolidated deposits is described as the Wissahickon Schist, a late Precambrian-early Paleozoic metamorphic rock unit of probable sedimentary origin, which is considered the basement rock in the area. The bedrock surface is irregular, and has an overall regional slope to the southeast.

The site is situated within the Delaware River Basin. The Delaware River forms a portion of the southern boundary of the study area and is the regional discharge point for both groundwater and surface water.

Two aquifer systems are present in the Delaware River Valley region. Groundwater occurs in both the unconsolidated deposits and in the underlying bedrock. The two flow systems are not interconnected in the study area due to the presence of local clay layers and a substantial thickness of weathered bedrock (saprolite) which inhibits the movement of groundwater between formations (BCM, 1986a). In the vicinity of the site, the unconsolidated deposits are a source for domestic and industrial groundwater supply. Most of the domestic water supply is now received from the Bristol Borough Water Authority, which is located east of the study area in Bristol, Pennsylvania. The bedrock groundwater flow system is of minor importance to groundwater supply in the vicinity of the site. There is currently no data describing any bedrock groundwater users in the local area, probably due to the ready availability of adequate groundwater supplies in the overlying unconsolidated deposits.

Although the study area encompasses about 3.5-square-miles, the Phase I RI was primarily focused on a 1-square-mile area of Croydon. This area was selected because (1) groundwater beneath it was known to be contaminated, (2) most of Croydon's industries were located within this area, and (3) 10 potential source areas were identified by the EPA Environmental Monitoring Systems Laboratory. This area, which is referred to as the "focused area of investigation," is located just north of the Rohm & Haas Site (see Figure 1-3 in Section 1.0).

The overall project goals for the Croydon TCE Site RI/FS are to determine the nature and extent of the threat posed by the release of hazardous substances and to evaluate alternatives for remedying the site problem(s). The overall objective is to collect the necessary data to determine the distribution and migration of contaminants, identify cleanup criteria, and

identify and support the remedial alternative evaluation. The objectives of the FS are to develop and evaluate the remedial action alternatives with respect to protection of public health and the environment, compliance with Applicable or Relevant and Appropriate Requirements (ARARs), and reduction of mobility and/or toxicity.

The scoping of the Phase I RI/FS was conducted during a 3-week period following the site reconnaissance of March 24, 1987. Because only a limited amount of information was available for the study area and the source(s) of the TCE groundwater contamination was unknown, a two-phased RI/FS was proposed to gather sufficient information to meet the project goals. The Phase I RI/FS objectives were subsequently identified and are outlined below.

- Characterize the nature and extent of groundwater contamination detected within the southeastern portion of the study area (i.e., the focused area of investigation).
- Assess the public health and environmental risks posed by groundwater within the study area.
- Determine the quality of local surface water to estimate the impact from groundwater discharge and estimate health and environmental risks associated with the use of these waters.
- Identify potential source areas that may be contributing to the groundwater contamination which is present within the southeastern portion of the study area.

Various field investigations were conducted to acquire the appropriate data to meet these objectives. These studies included a hydrogeologic investigation, a residential well survey/investigation, and a surface-water and sediment investigation. A limited amount of soil sampling was also undertaken in response to an EPA request. The request was made following a public meeting when a local resident indicated that fill material from the Rohm & Haas Landfill was placed throughout Croydon. Three separate areas were identified by the local resident.

The purpose of the hydrogeologic investigation was to characterize the nature and extent of TCE groundwater contamination, which was previously detected in the southeastern portion of the study area and to identify potential source areas that may be contributing to the groundwater contamination.

The purpose of the Surface Water and Sediment Investigation was to determine the impact of groundwater discharge on the local surface water to assess public health and environmental risks. Samples were collected from Neshaminy Creek, the Delaware River, and Hog Run Creek and its tributaries.

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As previously mentioned, a local concerned citizen indicated that several areas in Croydon contained fill material from the Rohm & Haas landfill. These areas included the concerned citizen's yard, the ballfields adjacent to the Mary Devine elementary school, and an area across from Rohm & Haas' Manufacturing Area B. EPA requested that during the Phase I RI, soil samples would be collected from those areas suspected of containing fill material. Soil samples were collected from these areas and analyzed for TCL organics, TAL metals, and cyanide.

A summary of the nature and extent of contamination identified in groundwater, surface water, sediment, and soil within the Croydon TCE Site study area is provided below.

- A plume of contaminated groundwater was identified in the southeastern portion of the study area. The plume appears to originate from one or two potential source areas which are located just north of U.S. Route 13. The plume extends south-southeast, in the direction of regional groundwater flow (see Figure 1-3 in Section 1.0). Trichloroethene and related compounds are the predominant contaminants.
- The occurrence and distribution of groundwater contamination suggests the possible presence of a second TCE plume originating from an offsite area east of Route 413. Localized groundwater flow is toward the northwest, opposite of the regional flow system in this area.
- Lead was detected above health-based standards in one out of forty residential well samples. This compound appears to be unrelated to groundwater contamination associated with the site.
- Surface water and sediments in Hog Run Creek and the pond behind the VFW Post contain relatively low levels of volatile organic compounds. Groundwater discharge to the surface water bodies is considered the source of these compounds.
- Sediments within the study area contain polycyclic aromatic hydrocarbons (PAHs) and slightly elevated levels of several inorganic constituents. These constituents are probably unrelated to contamination associated with the site.
- Surface soil samples were obtained from three areas where fill material from the Rohm & Haas landfill was allegedly placed. The samples contained PCBs, PAHs, and/or pesticides. It is unknown whether these compounds are associated with the Rohm & Haas landfill, represent background levels, or are attributed to another potential contaminant source.

A public health evaluation was conducted to determine the magnitude and probability of actual or potential harm to public health, welfare, and the environment associated with the actual or threatened release of hazardous substances from the Croydon TCE Site. This public health evaluation was based on the Phase I analytical chemical data and will be revised once the Phase II RI data are available. The baseline public health evaluation addressed the potential human health and environmental effects associated with the Croydon TCE Site under the no-action alternative.

Chemicals of potential concern were selected based on the sampling data of the environmental media and consideration of toxicity. Those selected for the groundwater pathways were divided by type of wells sampled--residential and monitoring--and included the following: chloroform, 4,4'-DDT (for monitoring wells only), 1,1-dichloroethane, 1,1-dichloroethene, dieldrin (for monitoring wells only), tetrachloroethene, 1,1,1-trichloroethane, and trichloro-ethene. The soil chemicals of potential concern were the carcinogenic polynuclear aromatic hydrocarbons (PAHs) and the polychlorinated biphenyls (PCBs). The surface-water chemicals of concern were 1,1,1-trichloroethane and trichloroethene, and the PAHs were selected as chemicals of potential concern for the sediments.

Under current land-use conditions at the Croydon TCE Site, the principal exposure pathways by which human receptors could potentially be exposed to site contaminants are as follows:

- Direct contact with surface soil contaminants (i.e., PAHs) by individuals using the ball fields.
- Direct contact with surface soil contaminants (i.e., PAHs, PCBs) by current residents.
- Ingestion of groundwater from residential wells in the southeastern portion of the study area.
- Inhalation of and dermal contact with chemicals of potential concern relating to groundwater released through household uses (showering, flushing the toilet, doing laundry, running the dishwasher, general kitchen uses, and cleaning).
- Direct contact with contaminated sediments from Neshaminy Creek and Hog Run Creek.

Average and plausible maximum exposure scenarios were developed for each of these pathways. The average case uses the geometric mean concentration and average exposure and intake assumptions. The plausible maximum case uses the maximum concentration detected and upper bound exposure assumptions. The exposure point concentrations of the chemicals of potential concern were estimated for potentially exposed populations. Human health

risks were assessed based on these estimates of exposure and a quantitative description of each compound toxicity. The major conclusions of this assessment are presented on Table ES-1 and summarized as follows:

- Exposure of baseball players through dermal contact and incidental ingestion could result in a potential, upper bound, excess lifetime cancer risks of 6×10^{-8} and 4×10^{-6} for the average and plausible maximum cases, respectively.
- Exposure of current residents through dermal contact and ingestion could result in a potential, upper-bound, excess lifetime cancer risk of 9×10^{-6} for the average case and 3×10^{-4} for the plausible maximum case.
- Ingestion of groundwater from residential wells could result in a potential, upper-bound, excess lifetime cancer risk of 2×10^{-6} for the average case and 1×10^{-4} for the plausible maximum case. Under the average and plausible maximum cases, the hazard index for noncarcinogenic exposure was less than one.
- Inhalation of volatile organics released from the groundwater during household use results in a potential excess, upper-bound, lifetime cancer risk of 4×10^{-6} for the average case. Under conditions of the plausible maximum case, the potential, excess, upper-bound, lifetime cancer risk was 2×10^{-4} . The hazard index was less than one for both the average and plausible maximum cases.
- Exposure to organic compounds in the groundwater through dermal absorption and inhalation while bathing could result in a potential upper bound excess lifetime cancer risk of 5×10^{-6} and 4×10^{-4} for the average and plausible maximum cases, respectively. The hazard index was less than one for both the average and plausible maximum cases.
- Individuals exposed to sediments in Neshaminy Creek through dermal contact could have a potential, lifetime, upper-bound, excess cancer risk of 3×10^{-8} under average exposure conditions. Under plausible maximum exposure conditions, the potential, lifetime, upper-bound, excess cancer risk is 3×10^{-6} .
- Children exposed to sediments in Hog Run Creek through dermal contact could result in a potential, upper-bound, excess lifetime cancer risk of 2×10^{-8} for the average case and 4×10^{-7} for the plausible maximum case.

AR300336

TABLE ES-1

SUMMARY OF RISK ASSESSMENT RESULTS FOR HUMAN EXPOSURE TO
CONTAMINANTS AT THE CROYDON TCE SITE

Exposure Pathway	Total Excess Upper-Bound Lifetime Cancer Risk		Hazard Index for Noncarcinogenic Effects	
	Average Case	Plausible Maximum Case	Average Case	Plausible Maximum Case
Direct Contact and Incidental Ingestion of Soil				
Baseball Players	6×10^{-8}	4×10^{-6}	NA	NA
Current Residents	9×10^{-6}	3×10^{-4}	NA	NA
Future Residents	6×10^{-6}	9×10^{-4}	NA	NA
Ingestion of Groundwater				
Residential Wells	2×10^{-6}	1×10^{-4}	<1	<1
Monitoring Wells	7×10^{-5}	2×10^{-3}	<1	<1
Inhalation of Volatile Organic Chemicals Released Indoors from Contaminated Groundwater				
Residential Wells	4×10^{-6}	2×10^{-4}	<1	<1
Monitoring Wells	7×10^{-6}	3×10^{-3}	<1	<1
Dermal Absorption While Bathing in Contaminated Groundwater				
Residential Wells	5×10^{-6}	4×10^{-4}	<1	<1
Monitoring Wells	2×10^{-5}	5×10^{-3}	<1	>1
Direct Contact with Sediments in Neshaminy Creek	3×10^{-8}	3×10^{-6}	NA	NA
Direct Contact with Sediments in Hog Run Creek	2×10^{-8}	4×10^{-7}	NA	NA

NA = Hazard index not calculated for this exposure pathway due to lack of RFDs for the chemicals of concern in the pathway.

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These exposure scenarios would apply for possible future land-use conditions. In addition, exposure to the groundwater chemicals of potential concern in the monitoring wells were evaluated as well as future residential exposure to soils.

- Ingestion of groundwater from the monitoring wells could result in a potential, upper-bound, excess lifetime cancer risk of 7×10^{-5} for the average case and 2×10^{-3} for the plausible maximum case. The hazard indices for both the average and plausible maximum exposure scenarios were less than one.
- Inhalation of volatile organic chemicals of concern released from groundwater during household activities resulted in lifetime, upper-bound, excess cancer risks of 7×10^{-6} and 3×10^{-3} for the average and plausible maximum cases, respectively. For both the average and plausible maximum cases, the hazard indices were less than one.
- Exposure to organic compounds in the groundwater through dermal absorption and inhalation while bathing could result in a potential, upper-bound, excess lifetime cancer risk of 2×10^{-5} and 5×10^{-3} for the average and plausible maximum cases, respectively. The hazard index for the average case was less than one; for the plausible maximum case, the hazard index was greater than one.
- Direct contact with contaminated soils by future onsite residents could result in a potential, upper-bound, excess lifetime cancer risk of 6×10^{-6} for the average case and 9×10^{-4} for the plausible maximum case.

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1.0 INTRODUCTION

NUS Corporation (NUS), under contract to Ebasco Services Incorporated (EBASCO), is pleased to submit this Final Phase I Remedial Investigation (RI) Report to the U.S. Environmental Protection Agency (EPA). Preparation of this Final Phase I RI Report was accomplished in response to Work Assignment Number 124-3LM7 under EPA Contract Number 68-01-7250 pursuant to the Final Phase I RI/FS Work Plan for the Croydon TCE Site dated August 1987.

The basis of concern at the Croydon TCE Site, Bucks County, Pennsylvania, primarily involves groundwater and surface-water contamination with trichloroethene (TCE). Within the study area, which is approximately 3.5 square miles, groundwater is used as the sole source of potable water by some of the residents. The majority of the homes within the study area, however, obtain their water from the Bristol Borough Water Authority. Prior to conducting this remedial investigation (RI) and feasibility study (FS), a limited amount of information for the study area was available. Additionally, the source of the groundwater contamination was unknown. Because of the large size of the study area and the fact that the source of the TCE contamination was unknown and little data existed, a two-phased RI was proposed.

The Phase I RI focused on defining the extent of the TCE groundwater plume and assessing the public health and environmental risks associated with TCE groundwater and surface water contamination. Objectives for the Phase I RI are provided below.

1. Characterize the nature and extent of groundwater contamination detected within the southeastern portion of the study area.
2. Assess the public health and environmental risks posed by groundwater within the study area.
3. Determine the quality of local surface water to estimate the impact from groundwater discharge and estimate health and environmental risks associated with the use of these waters.
4. Identify potential source areas that may be contributing to the groundwater contamination which is present within the southeastern portion of the study area.

Various studies and field investigations were conducted to meet these objectives. This Final Phase I RI Report presents the findings and conclusions of these studies, along with a baseline Public Health Evaluation.

Because the source of the contamination was unknown, the Phase I RI did not address source characterization. Rather, potential

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source areas that may be associated with the TCE groundwater contamination were identified during the Phase I RI. These potential source areas will be investigated during the Phase II RI, which has already been initiated by the preparation of a Final Phase II RI/FS Work Plan. The Final Phase II RI/FS Work Plan can be found in Appendix A of this report (see Volume II). The scope of work presented in the Phase II RI/FS Work Plan reflects the discussions/agreements of the Phase II Scoping Session, which was held on April 12, 1988, with EPA Region III personnel, and comments submitted by EPA Region III on July 29, 1988.

The remainder of this section describes the study area, the history of the site, and the previous investigations conducted at the study area. Section 2.0 describes the scope of work for the Phase I RI. Physical characteristics of the study area are presented in Section 3.0. The analytical results of the Phase I RI are discussed in Section 4.0 (Nature and Extent of Contamination). Section 5.0 presents the Public Health Evaluation and Risk Assessment. The supporting data (appendices) are provided in Volumes II and III of this report. The Final Phase II RI/FS Work Plan is provided in Appendix A.

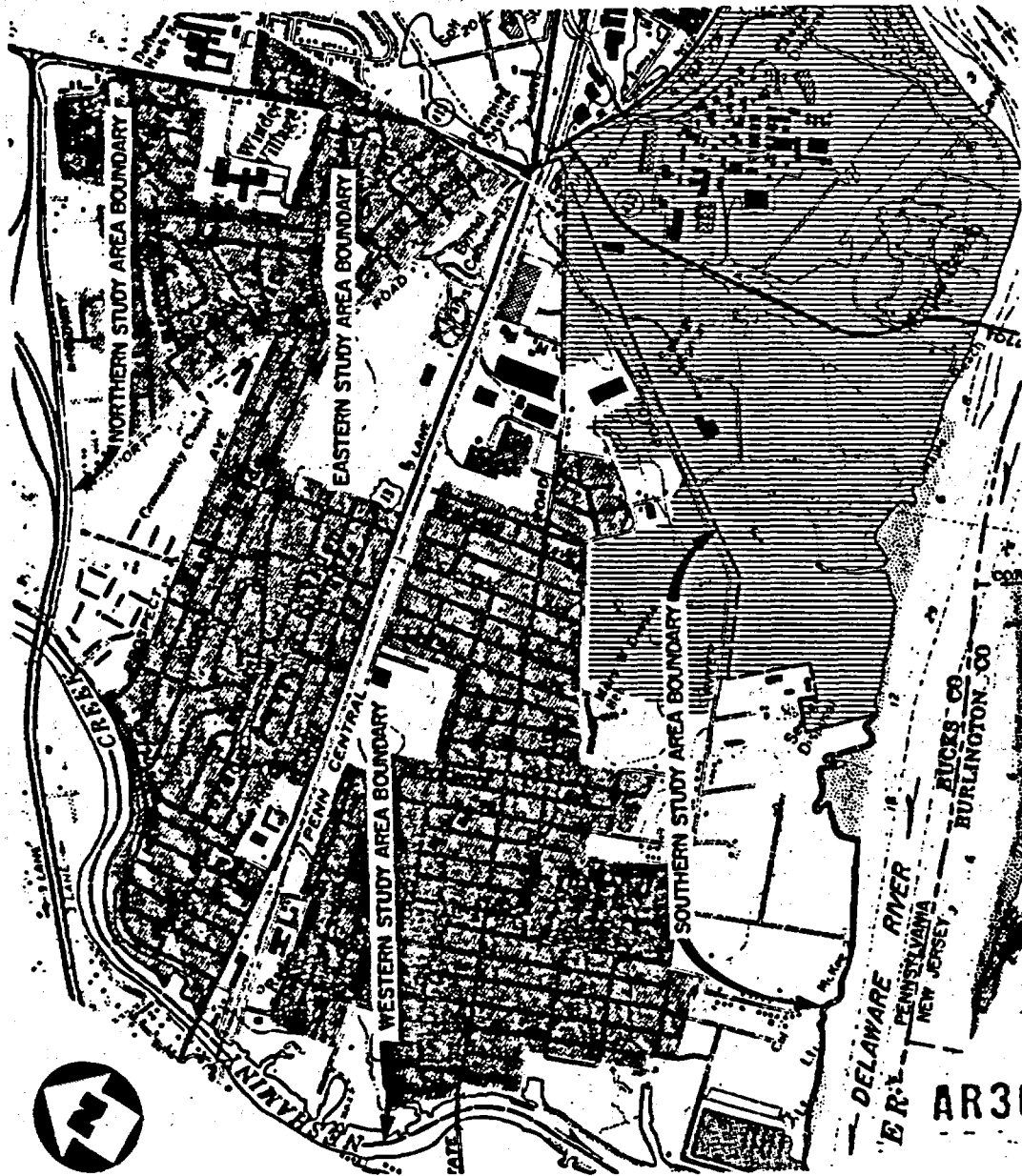
1.1 SITE BACKGROUND

1.1.1 Site Description

The Croydon TCE Site is located in Bristol Township, Bucks County, Pennsylvania (see Figure 1-1). Analytical data collected prior to this Phase I RI have revealed elevated levels of trichloroethene (TCE), tetrachloroethene (PCE), and other organic and inorganic contaminants in the groundwater and surface water. The source of this contamination is unknown, and therefore a "site" boundary was not established. However, a boundary for this investigation was established by EPA and will be referred to throughout this report as the "study area." This area encompasses approximately 3.5 square miles and is depicted in Figure 1-1.

As shown in Figure 1-1, the study area is bordered by Interstate 95 to the north, River Road and the Delaware River to the south, Neshaminy Creek to the west, and Route 413 to the east. The criteria for establishing the study area boundary were based on (1) potential widespread groundwater contamination in this portion of Bristol Township (BCM, 1986a), (2) potential source areas identified by the EPA Environmental Photographic Interpretation Center (EPIC), and (3) natural boundaries such as Neshaminy Creek and the Delaware River. Interstate 95 and Route 413, which comprise the northern and eastern borders of the study area, were selected only to limit the study area to a reasonable size.

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LEGEND

Study Area Boundary

Rohm and Haas Company Property



BASE MAP IS AN ENLARGEMENT OF A PORTION OF THE U.S.G.S. SEVENTY, PA-NJ QUAD-
RANGLE (7.5 MINUTE SERIES, 1968, PHOTOGRAPHIC 1975, CONTOUR INTERVAL 20 FEET)
AND A PORTION OF THE BRISTOL, PA-NJ QUAD-ANGLE (7.5 MINUTE SERIES, 1958, PHOTO-
GRAPHIC 1968, CONTOUR INTERVAL 20 FEET)

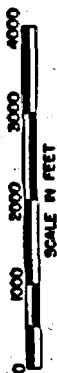


FIGURE 1-1



LOCATION MAP
CROYDON ICE SITE, BUCKS COUNTY, PA

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South of River Road (outside of the study area) is a large industrial landfill owned by Rohm & Haas Company (Rohm & Haas) and Chemical Leaman Tank Line, Inc. (BCM, 1988). At present, the landfill is being investigated by Rohm & Haas under a RCRA Corrective Action, based on data collected from various environmental media associated with the landfill (BCM, 1988). The landfill was also studied by Rohm & Haas to determine whether it was the source of the TCE groundwater contamination that is present in the southeastern portion of the study area (north of River Road). However, based on studies conducted to date by Rohm & Haas, TCE-contaminated groundwater is migrating toward the landfill area (i.e., southward toward the Delaware River) and not toward the study area (i.e., northward toward River Road). At this time, the source of the TCE contamination is not likely to be migrating from the Rohm & Haas Landfill. The landfill has not been included as part of the study area, based on these findings. Data collected during the Phase I RI support Rohm & Haas' findings.

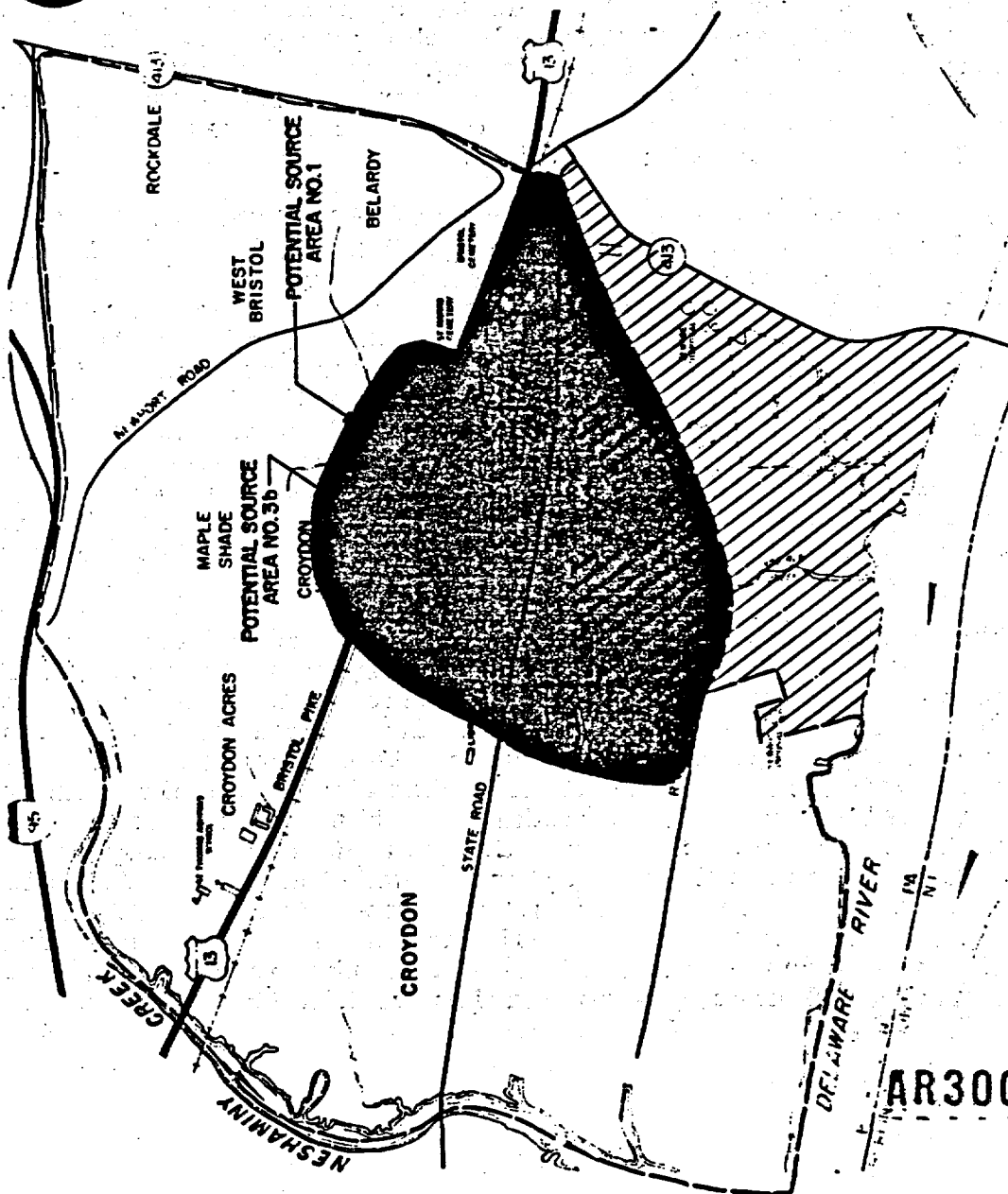
The Rohm & Haas Company property extends just north of River Road, but no landfilling or waste dumping by Rohm & Haas is known to exist in this area. This area of the company property is mainly undeveloped and does not contain any Rohm & Haas manufacturing facilities. It is being studied as part of this RI/FS, since groundwater beneath it is contaminated with TCE and other organic constituents.

As shown in Figure 1-2, the area north of River Road to U.S. Route 13, extending west of the Mary Devine Elementary School and east of Route 413, was studied extensively during the Phase I RI and has been referred to as the "focused area of investigation." The focused area of investigation lies within the "study area" and was studied extensively because (1) groundwater beneath this area was known to be contaminated with TCE, (2) surface water in this area was known to be contaminated, (3) 10 potential source areas within this area were identified through historical photographs, and (4) several small- to large-scale manufacturers were located in this area.

The focused area of investigation (see Figure 1-2), which is situated in the southeastern portion of the study area, includes a portion of the Croydon residential community and an area where several large- to small-scale manufacturing and commercial establishments are located. This area covers about 1 square mile. Most of the commercial establishments are located along State Road and U.S. Route 13. Most of the larger manufacturing facilities are located between these two roads in the southeastern portion of the focused area of investigation.

Hog Run Creek and its tributaries (i.e., East Branch and West Branch) are located within the focused area of investigation. The East and West Branches of Hog Run Creek emanate in the area between River Road and State Road and form Hog Run Creek just north of River Road (see Figure 1-2). Hog Run Creek then flows

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LEGEND

- Study Area Boundary
- Rohm and Haas Company Property
- Focused Area of Investigation

RESIDENTIAL AREAS

- Belardy
- Croydon
- Croydon Acres
- Croydon Heights
- Maple Shade
- Rockdale
- West Bristol

BUILDINGS

- 1 Netcoas Packaging
- 2 Alpha Aromatics
- 3 Bristol Flare
- 4 Mack Warehouse
- 5 Coyne Chemical



FIGURE 1-2



GENERAL ARRANGEMENT
CROYDON TCE SITE, BUCKS COUNTY, PA

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southward under River Road, between two Rohm & Haas landfills, and into the Delaware River.

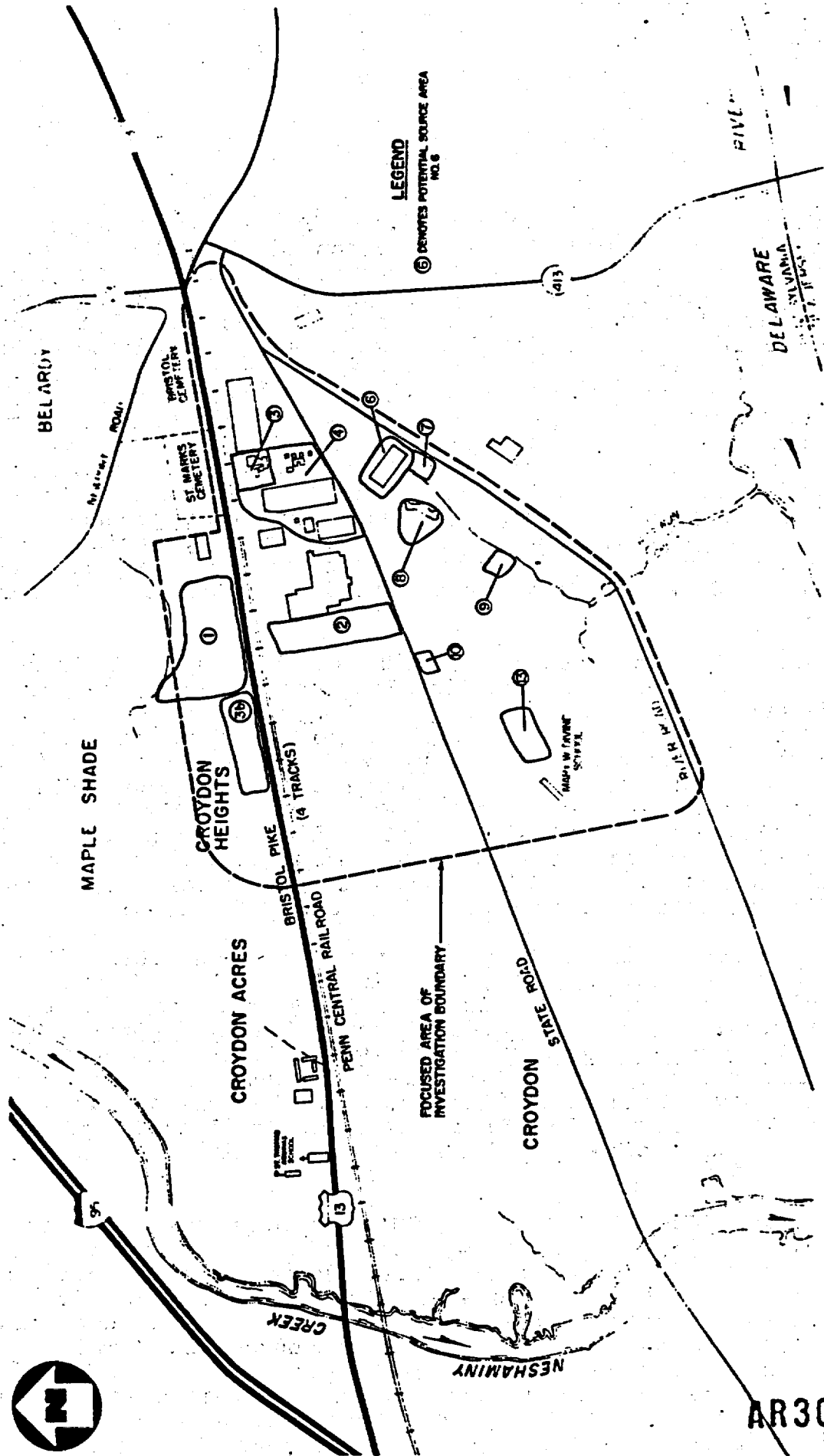
As mentioned previously, the Mary Devine School is located at the westernmost portion of the focused area of investigation. Approximately 500 children in grades kindergarten through sixth grade attend this school. Rohm & Haas previously owned approximately 23 acres of land, which included the school and surrounding grounds. However, it has been reported that no dumping was done in this area (BCM, 1988). Several athletic fields, which are still owned by Rohm & Haas, are situated east of the elementary school.

The Phase I RI centered on 10 potential source areas which are located within the focused area of investigation. These areas were identified by EPA in 1985 through a potential responsible party (PRP) search. The potential source areas, as shown in Figure 1-3, were analyzed by the EPA Environmental Photographic Interpretation Center (EPIC) using historical photographs. A narrative of each historical photograph is provided in Appendix B. The Phase I RI focused on determining the impact from each of the 10 potential source areas on groundwater contamination to identify which of the areas may be responsible for TCE groundwater contamination.

A second study was conducted by the EPA EPIC in 1987. This study focused on the area north of U.S. Route 13. A total of 10 "new" potential source areas were identified. A reconnaissance of each area was conducted by EPA Region III and the REM III Team in February 1988. Only 1 of the 10 potential source areas has been included for further study (Potential Source Area No. 3b). The other 9 potential source areas have been eliminated based on information collected during the site reconnaissance and the Phase I RI. Because the initial EPIC study had already identified a Potential Source Area No. 3 (see Figure 1-3), the second Potential Source Area No. 3 will be referred to as "3b." Potential Source Area No. 3b will be investigated during the Phase II RI.

For the most part, the remainder of the study area outside the focused area of investigation is mainly residential. With the exception of commercial establishments along State Road and U.S. Route 13, there are only a few small-scale, industrial manufacturing facilities outside the focused study area. Several residential communities, which were mainly constructed in the 1940s to 1960s, make up the study area. These communities include Croydon, Croydon Heights, Croydon Acres, Maple Shade, West Bristol, Belardy, and Rockdale. According to 1980 U.S. Census Bureau figures, approximately 67,500 people live in Bristol Township. Population figures were not available for the individual communities within the study area; however, it is estimated that the population within the study area could range from 2,000 to 3,000 people.

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NOTE: POTENTIAL SOURCE AREAS NO. 5, 11, AND 12 ARE LOCATED OUTSIDE OF THE STUDY AREA ON THE ROBIN & HAAS COMPANY PROPERTY

FIGURE 1-3



PHASE 1 POTENTIAL SOURCE AREAS
CROYDON TCE SITE, BUCKS COUNTY, PA

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1.1.2 Site History

The Croydon TCE Site was identified by EPA after a series of events led to a remedial investigation of the Rohm & Haas Site, which forms part of the southern boundary of the Croydon TCE Site study area. The series of events began in 1978 when a congressional investigating subcommittee was formed to examine the potential threats posed by hazardous waste disposal sites across the country. The subcommittee requested waste disposal information from 53 of the largest chemical companies in the country. One of these companies, the Rohm & Haas Company, reported that hazardous wastes produced by the company were disposed of on the company's property in Croydon, Bristol Township. Following a recommendation from the subcommittee, the EPA inspected the property and discovered that groundwater and surface water on the site were contaminated by various organic compounds. In addition, groundwater contained heavy metals that exceeded Federal drinking water standards (Ebasco, Incorporated 1988).

Also in 1980, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), better known as "Superfund." This act provided the state and Federal governments with the authority to address abandoned or uncontrolled hazardous waste disposal sites and established a fund for remediating the sites once they were identified. As required by the new law, Rohm & Haas notified the EPA that the wastes disposed on its Bristol Township property included 43 tons of RCRA-hazardous waste by definition, or had components listed as hazardous (BCM, 1988). Total process waste in the landfill is estimated to be 268,000 tons (BCM, 1988).

Subsequently, in 1983, Rohm & Haas hired a consulting firm, BCM Eastern Incorporated (BCM), to conduct studies of its Bristol Township property. Following its investigations, BCM released two reports: Report on Landfill Investigation, April 1984, and Landfill Investigation, February 1985. The reports concluded that the property posed no threat to human or environmental health. Nevertheless, the EPA proposed the Rohm & Haas Site for the National Priorities List (NPL) in April 1985 and thereby identified the site for long-term remedial action under the Superfund Act.

Under the REM III Program, BCM's reports were reviewed by Ebasco, Incorporated (Ebasco), for EPA. Ebasco submitted a report to EPA in November 1985 that identified some deficiencies in the BCM reports. However, Ebasco concurred with BCM's conclusions, which suggested that a plume of contaminated groundwater emanates from a source or sources in Croydon and is migrating onto the Rohm & Haas property. Although the contaminant plume contains some compounds present in the Rohm & Haas landfill, particularly TCE, there was evidence to suggest that the Rohm & Haas Company was not responsible for this plume. Because the source of the contaminated plume was not identified

and because many of the businesses in the area may also use products containing TCE, the EPA determined that a separate RI/FS was required to characterize the nature and extent of the contamination, assess the public and environmental health risks associated with the contamination, and identify potential remedial alternatives.

In April 1985, the NUS Corporation Field Investigation Team (FIT) prepared a Hazard Ranking Score (HRS) for the Croydon TCE Site. An HRS of 31.60 was calculated. This score was based on the findings of the Rohm & Haas investigations, which included data for groundwater, surface water (Hog Run Creek), and sediments in the southeastern portion of the Croydon TCE study area. Because the source of contamination was unknown, a site boundary could not be established. In September 1985, the Croydon TCE Site was selected for inclusion on the National Priorities List (NPL) and ranked 616th.

1.1.3 Previous Investigations

The studies conducted to date at the Croydon TCE Site are limited and were primarily focused only on the southeastern portion of the study area between River Road and State Road. Most of the sampling conducted in this area was performed by BCM to determine whether TCE was migrating from or onto the Rohm & Haas property. These studies involved the construction and sampling of more than 25 monitoring wells, surface water and sediment sampling of Hog Run Creek and its tributaries, residential well sampling, an aquatic survey of Hog Run Creek, and soil sampling near the Mary Devine Elementary School. The primary report, which contains the results of the above sampling efforts, is TCE Groundwater in the Vicinity of River Road, Bristol Township, Pennsylvania, March 1986. Other BCM reports which have utilized information obtained from the study area, but primarily focused on the landfill south of River Road, include the following:

- Report on Landfill Investigation, April 1984.
- Landfill Groundwater Sampling (February and July 1985, May 1986).
- Aquatic Baseline Survey of Hog Run Creek, May 1986.
- Landfill Remedial Investigation Report Addendum, March 1988.

With the exception of the field sampling conducted under this Work Assignment, a limited amount of sampling was conducted by EPA in the Croydon study area. Sampling efforts conducted by EPA (Field Investigation Team - Region III) include the collection of samples from residential wells, sampling of Rohm & Haas wells north of River Road, and surface water and sediment sampling of Hog Run Creek. No previous investigations have been conducted outside of the focused area of investigation (i.e.,

southeast portion of the study area) to determine the source of the TCE contamination or the extent and nature of the TCE-contaminated groundwater.

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2.0 STUDY AREA INVESTIGATION

2.1 PHASE I OBJECTIVES

The overall project goals for the Croydon TCE Site RI/FS are to determine the nature and extent of the threat posed by the release of hazardous substances and to evaluate alternatives for remedying the site problem(s). The overall objective of the RI is to collect the necessary data to determine the distribution and migration of contaminants, identify cleanup criteria, and identify and support the remedial alternative evaluation. The objectives of the FS are to develop and evaluate the remedial action alternatives with respect to protection of public health and environment, compliance with Applicable or Relevant and Appropriate Requirements (ARARs), and a reduction of mobility and/or toxicity.

The scoping of the Phase I RI/FS was conducted during a 3-week period following the site reconnaissance of March 24, 1987. Because only a limited amount of information was available for the study area and the source(s) of the TCE groundwater contamination was unknown, a two-phased RI/FS was proposed to gather sufficient information to meet the project goals. Phase I RI/FS objectives were subsequently identified and are outlined on Table 2-1. Criteria for meeting these objectives were also established and are also given in Table 2-1. The REM III Project Team then identified the various investigations and data collection activities that are necessary to meet the criteria (these are also given in Table 2-1). The scope of work conducted under these investigations is described below.

2.2.1 Hydrogeological Investigation

The purpose of the hydrogeologic investigation was to (1) characterize the nature and extent of TCE groundwater contamination, which was previously detected in the southeastern portion of the study area and (2) to identify potential source areas that may be contributing to the groundwater contamination. The scope of work employed during the hydrogeologic investigation is summarized below.

- Installed and developed 29 wells at 15 locations to monitor groundwater quality within the focused area of investigation. Each location, with the exception of well location No. 10, consisted of one shallow (approximately 20-foot) and one deep (approximately 50-foot) well. Location No. 10 consisted only of a deep well that was installed adjacent to an existing shallow well (LF-14-20). The locations were established to monitor groundwater at each potential source area. With the exception of Potential Source Areas 3b, 6, and 7, the Phase I RI was able to assess groundwater upgradient and downgradient from each potential source area. Potential Source Areas 3b, 6, and 7 will be assessed during the Phase II RI.

TABLE 2-1
PHASE I RI/FS OBJECTIVES, CRITERIA, AND DATA COLLECTION ACTIVITIES
CROYDON TCE SITE

Phase I RI/FS Objectives	Criteria for Meeting Objectives	Data Collection Activities
1. Characterize the nature and extent of groundwater contamination which was previously detected in the southeastern portion of the study area.	<ul style="list-style-type: none"> • Delineate the contaminant plume boundaries. • Determine groundwater flow rates and direction. • Determine subsurface lithology. • Determine aquifer characteristics. 	<ul style="list-style-type: none"> • Installed 29 monitoring wells at 15 well locations. • Sampled 19 existing wells (installed by BCM for Rohm & Haas) and 29 newly-installed wells. Analyzed for TCL volatile organics, TCL base/neutral/acid extractable organics, PCBs, pesticides, TAL inorganics, and water quality parameters were analyzed for selected wells. • Sampled 40 residential wells and analyzed for TCL volatiles. TCL base/neutral/acid extractable organics, PCBs, pesticides, TAL inorganics, and water quality parameters were analyzed for selected wells. • Obtained 2 rounds of water-level measurements on newly-installed wells, and 19 Rohm & Haas wells. • Continuously recorded static water levels on selected wells to assess impact from tidal fluctuations. • Performed in-situ slug tests on newly-installed wells.

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TABLE 2-1
 PHASE I RI/FS OBJECTIVES, CRITERIA, AND DATA COLLECTION ACTIVITIES
 CROYDON TCE SITE
 PAGE TWO

Phase I RI/FS Objectives	Criteria for Meeting Objectives	Data Collection Activities
2. Assess the public health and environmental risks posed by groundwater within the study area.	<ul style="list-style-type: none"> Determine groundwater quality of domestic well users within the study area. 	<ul style="list-style-type: none"> Attempted to identify domestic well users within the study area. (A questionnaire was forwarded to 482 potential well owners during the preparation of the Phase I RI/FS Work Plan. The potential well owners represented homes that were located along streets which did not have service to a public water supply.) Streets without the service of a public water supply were identified. Sampled 40 domestic wells and analyzed for TCL volatiles. TCL B/M/A extractables, PCBs, pesticides, TAL inorganics, and water-quality parameters were analyzed for selected wells.
3. Determine the quality of local surface waters to estimate the impact from groundwater discharge and estimate health risks associated with the use of these waters.	<ul style="list-style-type: none"> Identify streams of concern for risk characterization. Determine surface water and sediment quality. Estimate groundwater/surface water interaction. 	<ul style="list-style-type: none"> Conducted a site reconnaissance and reviewed site location maps to identify streams that are within or near the study area. Sampled study-area surface waters (including sediments) and analyzed for TCL organics and inorganics via GLP routine analytical services. Obtained at least two complete rounds of water-level measurements on selected monitoring wells and Hog Run Creek (via staff gauges).

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TABLE 2-1
 PHASE I RI/FS OBJECTIVES, CRITERIA, AND DATA COLLECTION ACTIVITIES
 CROYDON TCE SITE
 PAGE THREE

Phase I RI/FS Objectives	Criteria for Meeting Objectives	Data Collection Activities
4. Identify potential source areas that may be contributing to the groundwater contamination, which is present throughout the southwestern portion of the study area.	<ul style="list-style-type: none"> ● Delineate contaminant plume(s). ● Determine upgradient/downgradient groundwater quality at each of the 10 potential source areas. 	<ul style="list-style-type: none"> ● Same as objective number 1.
5. Assess quality of soils allegedly used as fill material.	<ul style="list-style-type: none"> ● Determine soil quality in areas suspected of containing fill material. 	<ul style="list-style-type: none"> ● Collect surface soil samples from ballfield area, local residents property, and across from Manufacturing Area B.

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- Conducted in-situ hydraulic conductivity tests (i.e., slug tests) at all 29 newly installed wells (i.e., REM III wells) and 2 wells (LF-14-20 and LF-13-43) that were owned by Rohm & Haas.
- Conducted a short-term pumping test at well cluster No. 11.
- Collected samples from the 29 REM III wells and 17 existing wells (i.e., Rohm & Haas wells) within the study area. All samples were analyzed for Target Compound List (TCL) volatile organics by the EPA Central Regional Laboratory (CRL) in Annapolis, Maryland, using EPA Method 624. Selected samples were analyzed for base/neutral/acid (B/N/A) extractable organics, PCBs, pesticides, Target Analyte List (TAL) metals, cyanide, and water chemistry parameters (total organic carbon, biological oxygen demand, nitrates, nitrites, sulfates, total dissolved solids, total suspended solids, chlorides, carbonates, bicarbonates, and ammonia).

Drilling activities, including the development of all 29 REM III wells, were conducted during the period October 19, 1987 to December 8, 1987. It was anticipated that the drilling activities would conclude on or about November 18, 1987; however, a number of problems were encountered during the course of the drilling operations. These problems primarily included equipment failure, inclement weather, auger refusal, auger breakage, and running sands.

Thirteen Rohm & Haas wells were sampled by the REM III Team during the period November 11 to November 12, 1987. Four other existing wells were sampled on December 15, 1987. One Rohm & Haas well cluster, CR-25, could not be located and therefore was not sampled as originally planned. This well cluster location was later identified and will be sampled during the Phase II RI (see Appendix A - Phase II RI/FS Work Plan).

As mentioned previously, all groundwater samples were analyzed for TCL volatile organics via EPA Method 624 at the EPA-CRL in Annapolis, Maryland. Since groundwater contamination was limited primarily to TCE (and other chlorinated solvents), only a limited number of wells were analyzed for B/N/A extractable organics, PCBs, pesticides, TAL metals, cyanide, and water chemistry parameters. Samples for "full analysis" were collected from monitoring wells LF-13-18, LF-13-43, LF-15-26, and LF-15-37.

During the period December 7 to December 10, 29 REM III Team wells were sampled. All samples were analyzed for TCL volatiles (EPA Method 624) at the EPA-CRL. Selected samples were analyzed for B/N/A extractable organics, PCBs, pesticides, TAL metals, cyanide, and water chemistry parameters. These samples were collected from MW3(S), MW3(D), MW5(S), MW5(S), MW13(S), and MW13(D).

Static water-level measurements were obtained from selected REM III and Rohm & Haas monitoring wells on January 6, January 9, February 29, and March 25, 1988. In-situ conductivity tests (i.e., slug tests) were performed during the period January 4 to 9, 1988. During this period, seven wells were monitored continuously with a Stevens Strip-Chart Recorder to assess the influence of the tide on groundwater within the focused area of investigation.

Deviations from the original scope of work include the following:

- Well cluster No. 14 was not installed near Route 413 (on the property of the Bristol Cemetery) due to problems obtaining site access. After discussing the problem with EPA, a decision was made to install this cluster downgradient from Coyne Chemical Incorporated to determine whether TCE may be emanating from Potential Source Area No. 4.
- Well cluster CR-25 was not sampled because it could not be located in the field; however, the well cluster was later found and will be sampled during the Phase II RI.

2.2.2 Residential Well Survey/Investigation

Previous sampling efforts conducted by FIT III and BCM indicated that a number of residential wells and monitoring wells in the area between River Road and U.S. Route 13 exhibited levels of TCE above drinking water standards. Because the extent of the TCE plume was unknown, it was necessary to identify and sample those residences in the study area which were not serviced by the Bristol Borough Water Authority. Additionally, by sampling residential wells throughout the 3.5-square mile study area, groundwater quality could be evaluated without the expense and time involved with constructing new monitoring wells.

Tax maps of the entire study area were obtained by the REM III Project Team. A water distribution map, which indicated the location of the public water supply lines in the study area, was also obtained so that those streets not serviced by a public water supply could be identified. Parcel numbers (i.e., properties) along "non-serviced" streets were then identified, and a listing of current property owners was obtained from the Bucks County Courthouse.

During the preparation of the Phase I RI/FS Work Plan, a questionnaire was prepared and distributed to 482 property owners along streets suspected of being without the service of public water. The questionnaire requested information as to whether the residence had or used a domestic well. Other information, such as the number and age of people living in the household, telephone numbers, uses of the domestic well (i.e., drinking, cooking, washing cars, watering the lawn), and well

construction details were also requested. The questionnaire also requested permission for EPA to collect a sample from the domestic well for chemical analysis.

The results of the questionnaire are summarized below.

74	Reported no well and were on public water
7	Reported no building or home on the property (i.e., vacant)
41	Reported that their home has a well
360	Not returned
482	

Following receipt of the questionnaire, 41 residential well owners were identified and contacted by telephone to arrange a convenient time for sampling. In addition to receiving these questionnaires, seven homeowners contacted EPA following a public meeting and requested that their wells be sampled. Sampling was conducted during the period October 28 to November 4, 1987. Eight of the 48 residential wells were not sampled due to well access problems (i.e., the well was not in use and was covered with a concrete slab) or to "last-minute" refusals by the homeowners. Four residential wells (RW19 through RW22) had to be resampled on December 15, 1988, because of bottle breakage during shipping.

All samples were analyzed for TCL volatile organics via EPA Method 601/602. Fast turnaround of the analytical results (21 days) was requested to identify those residences which were at a high public health risk (i.e., $>10^{-4}$). Eight residential well samples (RW1 through RW8) were also analyzed for TCL B/N/A extractable organics, PCBs, pesticides, TAL metals, and cyanide in addition to TCL volatiles. Additionally, 10 residential well samples (RW30 through RW39) were analyzed for selected water chemistry parameters.

A number of duplicate samples, trip blanks, and bottle blanks were also collected during the sampling of residential wells to assess quality assurance/quality control (QA/QC) during both the collection and analysis of the samples. The QA/QC samples are given below.

- Field Blank - collected on 12/15/87.
- Bottle Blank - collected on 10/28/87.
- Trip Blanks - collected on 10/28/87, 11/6/87, 11/12/87 (2), and 12/15/87.
- Duplicates - collected for RW6, RW8, RW29, and RW32.

Section 4.1 discusses the findings of this investigation.

2.2.3 Surface-Water and Sediment Investigation

Previous sampling efforts conducted by BCM and EPA focused on Hog Run Creek and its tributaries, and the Delaware River to meet the criteria for Phase I RI/FS Objective Number 3.

(determine the quality of local surface waters so as to estimate the impact from groundwater discharge and estimate health risks associated with the use of these waters), the REM III Project Team collected surface-water and sediment samples from the following areas:

Surface Water	Location No.	Description
Neshaminy Creek	SW1	Collected approximately 1/2 mile north of Interstate 95.
	SW2	Collected approximately 1/2 mile south of Interstate 95.
	SW3	Collected from an inlet along the creek, approximately 1,000 feet north of State Road.
	SW4	Collected just north of State Road bridge.
	SW5	Collected near confluence with Delaware River.
Hog Run Creek	SW13	Collected north of River Road.
	SW14	Collected south of River Road.
East Branch Hog Run Creek	SW11	Collected downstream from the onsite pond area.
	SW12	Collected approximately 50 yards from confluence with Hog Run Creek.
West Branch Hog Run Creek	SW10	Collected approximately 50 yards from confluence with Hog Run Creek.
Delaware River	SW9	Collected about 100 yards upstream of confluence with Neshaminy Creek.
Pond behind VFW	SW15	Collected near west bank of pond.
Pond behind VFW	SW16	Collected near north bank of pond.

All samples were collected during the period December 16 to 17, 1988. Sample location numbers SW6 through SW8 were not sampled because of time constraints. These samples were to be taken along the Delaware River upstream and adjacent to the study area. Surface water samples SW17 through SW21 were not collected due to dry conditions. These samples were to be taken from various unnamed intermittent streams throughout the study area. Sample locations SW6 through SW8, SW18, and SW19 will be sampled during the Phase II RI if water is present. Location numbers SW18 and SW19 are along an intermittent stream, which is located north of Potential Source Area No. 1.

All surface-water samples were analyzed for TCL organics, TAL metals, and cyanide. Sediment samples were analyzed for TCL volatiles and B/N/A extractable organics, TAL metals, and cyanide.

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The following QA/QC samples were collected during the Phase I Surface Water and Sediment Investigation:

- Surface Water Field Blank - collected on 12/17/87
- Sediment Field Blank - collected on 12/16/87
- Surface Water Bottle Blank - collected on 12/17/87
- Surface Water Trip Blank - collected on 12/17/87
- Sediment Trip Blank - collected on 12/16/87
- Duplicates - collected at sample location SW13 and SD13

Section 4.2 presents and discusses the results of this investigation.

2.2.4 Surface Soil Investigation

During the scoping of the Phase I RI/FS, no soil sampling was proposed, since the source area(s) was not yet identified. During the public meeting, however, a local concerned citizen indicated that several areas in Croydon contained fill material from the Rohm & Haas landfill. These areas included the concerned citizen's yard, the ballfields adjacent to the Mary Devine school, and an area north of River Road across from Manufacturing Area B. EPA requested that, during the Phase I RI, soil samples would be collected from those areas suspected of containing fill material.

Soil samples were collected from the athletic fields near the Mary Devine school (SO-5 through SO-8), the property of a local resident near River Road (SO-1 and SO-2), and from an area across from Manufacturing Area B (SO-3 and SO-4).

All samples were analyzed for TCL organics, TAL metals, and cyanide. A duplicate sample was collected at sample station No. SO-5. Section 4.3 presents and discusses the results of this investigation.

2.2.5 Aerial Survey and Topographic Mapping

Two topographic maps were prepared using aerial photogrammetric means. One topographic map includes the entire 3.5-square-mile study area and reflects a scale of 600 feet = 1 inch. This map is contoured at 5-foot intervals. The second topographic map depicts the focused area of investigation and was prepared at a scale of 300 feet = 1 inch with 2-foot contours.

Both maps have been used throughout this report to help describe groundwater flow, extent of contamination, and sample locations. Each map will also be used extensively during the feasibility study and will be beneficial during the design and construction phases at this site.

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3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The geology, soils, and surface-water hydrology sections were derived from a literature review, whereas the hydrogeology discussion is mainly the result of the field investigation.

3.1 GEOLOGY

The geology of the Croydon TCE Site consists of unconsolidated sand, gravel, silt, and clay deposits overlying metamorphic bedrock. The site is located within the Coastal Plain physiographic province, approximately 4 miles southeast of a northwest-trending outcrop of metamorphic rocks that forms what is referred to as the fall line. A narrow band of metamorphic bedrock is exposed south of the fall line along the stream valley of Neshaminy Creek (Greenman, 1955). This outcrop area extends southward along the stream to just south of U.S. Route 13, in the northwestern part of the study area.

Unconsolidated deposits within the Delaware River Valley consist of Upper Cretaceous sediments of the Raritan Formation and Quaternary age deposits, primarily Pleistocene (Wisconsin) age glacial outwash in the form of valley fill deposits, which are overlain by a thin veneer of recent alluvium. The Quaternary outwash deposits are generally erratic and discontinuous, and are made up primarily of sand and gravel with minor amounts of silt and clay. These deposits have a generally fining, upward trend. Recent alluvium forms a thin veneer overlying the valley fill deposits and consists primarily of fine-grained flood-plain and channel deposits. Total thickness of the unconsolidated deposits in well borings ranged from 29 to 69 feet in the study area and from 40 to 65 feet in borings south of the study area (BCM, 1986a).

The Upper Cretaceous sediments of the Raritan Formation lie beneath the Quaternary deposits unconformably over a Pre-Cambrian basement rock. The Raritan Formation consists of a series of nonmarine sedimentary sequences of gravel, sand, and clay. In the location of the study area, the formation is defined by a dense clay lying unconformably on the bedrock (Greenman, 1955, Owens and Manard, 1964). This deposit, the Upper Clay Unit, was not distinguished in the study area.

Bedrock underlying the unconsolidated deposits is described as the Wissahickon Schist, a late Precambrian, early Paleozoic metamorphic rock unit of probable sedimentary origin, which is considered the basement rock in the area. This unit is described as being gneissic to schistose in character, with abundant mica and significant amounts of feldspar, quartz, and chlorite. Foliation of platy minerals within the unit generally strikes northeast, and both the foliation and relict bedding within the formation have overall dips to the southeast (Kammerer, 1953). The bedrock surface is irregular and has an overall regional slope to the southeast.

Boring logs show a well developed clay/saprolite (weathered bedrock) at the sediment/bedrock interface. The saprolite is continuous in the vicinity of the site, is micaceous and clayey in nature and the surface is irregular and undulating.

3.2 SOILS

Soils in the study area consist of gently sloping, mostly well-drained, permeable materials developed on Delaware River Valley terraces. These deposits consist of the Pope loam terrace, Alton gravelly loam, Fallsington silt loam, and Urban land. The Fallsington silt loam is the only deposit that is poorly drained. This deposit occurs along the East and West Branch of Hog Run Creek. The soils consist of loams, sandy loams, or gravelly loams in the upper horizon that were formed from loamy and/or gravelly alluvial sediments. Approximately 50 percent of the site area is mapped as urban land (USDA-SCS, 1975).

3.3 SURFACE-WATER HYDROLOGY

The site is situated within the Delaware River Basin. The Delaware River forms a portion of the southern boundary of the study area and is the regional discharge point for both groundwater and surface waters. Neshaminy Creek, flowing southward along the western edge of the study area, is a major tributary of the Delaware River. Groundwater from the western edge of the study area is expected to discharge into this creek. Hog Run Creek, located along the southern and southeastern study area boundary, is a minor tributary to the Delaware River. Shallow groundwater in the southeastern part of the study area discharges to this stream. The deep groundwater flow also discharges to Hog Run Creek and the Delaware River.

Surface water of the Delaware River is tidal-influenced up to and beyond Trenton, New Jersey (NOAA, 1987). The lower stretches of both Neshaminy Creek and Hog Run Creek (south of the study area) are influenced by the tides. The tidal influence on Hog Run Creek does not extend up to the study area, whereas the tidal influence on Neshaminy Creek extends into the southwestern part of the study area.

The tidal fluctuation of the Delaware River was calculated for the Burlington, New Jersey, subordinate station (latitude: 40°05'W. longitude: 74°52'W). This station is located 1 mile southeast of monitoring well location CR-MW15. Surface-water levels during the period of January 4, 1988, to January 8, 1988, ranged from a high of 6.3 feet to a low of 0.1 foot above the mean datum of the Delaware River (Appendix C).

3.4 HYDROGEOLOGY

Two aquifer systems are present in the Delaware River Valley region. Groundwater occurs in both the unconsolidated deposits and in the underlying bedrock. The two flow systems are not interconnected in the study area because of the presence of

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local clay layers and a substantial thickness of weathered bedrock (saprolite), which inhibits the movement of groundwater between formations (BCM, 1986a).

Groundwater in the unconsolidated deposits occurs mainly under unconfined conditions. Occasional, low-permeability silt and clay deposits create isolated confining layers. However, the lateral extent of any individual unit is small, and the local, semiconfined conditions created are not expected to be of major importance.

In the vicinity of the site, the unconsolidated deposits are a source for domestic and industrial groundwater supply. Most of the domestic water supply is now received from the Bristol Borough Water Authority, which is located east of the study area in Bristol, Pennsylvania.

The bedrock groundwater flow system is of minor importance to groundwater supply in the vicinity of the site. There are currently no data describing any bedrock groundwater users in the local area, probably because of the ready availability of adequate groundwater supplies in the overlying, unconsolidated deposits. Groundwater occurrence and movement in the metamorphic bedrock beneath the site is controlled primarily by fractures, with schistosity, cleavage, and bedding planes also contributing factors. Primary porosity within the bedrock unit is essentially nonexistent, as is typical of crystalline bedrock units. Where groundwater is obtained from the unit for water supply (in areas to the northeast), the overall water quality is good, with low hardness and total dissolved solids (TDS) (Hall, 1973; Greenman, 1955).

3.4.1 Monitoring-Well Installation

Twenty-nine, 2-inch, schedule 40 PVC, monitoring wells with 10-foot, 20-slot well screens were installed by hollow-stem-auger drilling methods. An organic-free bentonite mud was used in the later drilling stages of CR-MW04(D) and CR-MW10(D). This was necessary to keep the formation from collapsing into the hole before monitoring-well installation was complete. These wells were the first two drilled. Subsequent wells did not require drilling mud, since the drillers developed a technique for keeping the boring open long enough to install the well.

The deep wells were drilled to the clay/saprolite layer. The bottom of the well was then positioned 1 to 3 feet above this layer of impermeable material. For the shallow wells, the top of the well screen was set approximately 2 feet above the water table. The average depth for the deep wells was 48 feet; the maximum and minimum depth was 68 feet and 30 feet, respectively. The average depth for the shallow wells was 20 feet; the maximum and minimum depth was 29.5 feet and 14 feet, respectively.

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Split-spoon samples were taken at 5-foot intervals to obtain lithologic descriptions, which are recorded on the boring logs in Appendix D.

The monitoring wells were developed after all the wells were installed. Well-development methods included pumping with vacuum and lift pumps and by air lift (air compressor). Well-development water was discharged onto the ground. No elevated readings were recorded on the HNu instrument during well evacuations; however, a white, immiscible liquid was observed on several wells after a few minutes of pumping (this is described further in Section 4.1).

3.4.2 Hydrogeologic Cross Sections

Three hydrogeologic cross sections were constructed from the lithologic data recorded on the boring logs (Appendix D), well construction forms (Appendix E), and static water-level data collected on February 29, 1988 (Appendix F). Figure 3-1 identifies the locations of the cross sections. The cross sections are shown in Figure 3-2. The first hydrogeologic cross section (A-A') trends west to east through the study area and is nearly parallel to the Delaware River and perpendicular to the direction of groundwater flow. The other two cross sections (B-B' and C-C') trend north to south and are approximately parallel to the direction of groundwater flow. Static water levels are above the top of the well screen in the shallow monitoring wells due to seasonal fluctuations.

The major hydrogeologic unit described on these cross sections is a coarse alluvium that consists mainly of medium to coarse sand, gravel, cobbles, and some silt. This deposit is saturated, is the main water-bearing formation, and is under unconfined aquifer conditions. Within this unit, a cobble layer was encountered at many well locations south of U.S. Route 13 at a depth between 14 to 21 feet. Usually this zone was about 2 to 3 feet thick with cobbles ranging in size from 1 inch to 6 inches in diameter. Occasionally, larger boulders were encountered which prevented further drilling. The cobble layer consisted of well-rounded quartzite and schist-gneiss cobbles with about 25 percent consistency of gravel and coarse sand. Above the cobble layer was a generally fining, upward sequence, transforming from gravel and sand to medium and fine sand. Deposits below the cobble layer consisted mainly of medium-grained sand and gravel.

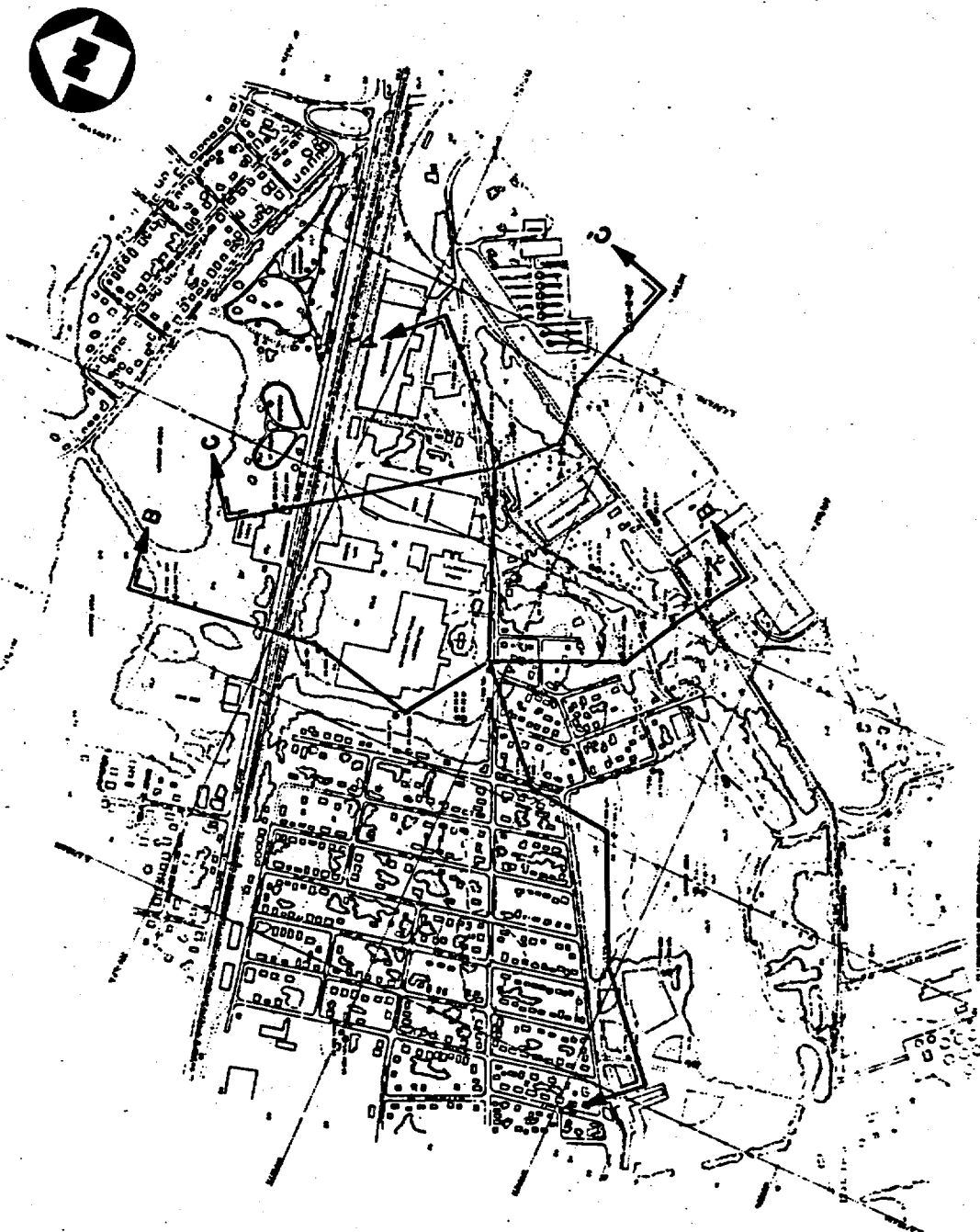
A deposit of fine sand and silt overlies the coarse alluvium at locations where the surface elevation is above 20 feet. This deposit of finer sediments is unsaturated except in the vicinity of Hog Run Creek. Isolated lenses of silty sands, silty clays, and clays are present but are not believed to have any major effect on groundwater flow. The clay lense present at CR-MW04 and CR-MW14 (Figure 3-2, A-A') may be creating confining conditions in this area; thus, it might also isolate this section of Hog Run Creek from the groundwater.

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FIGURE 3-1



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HYDROGEOLOGIC CROSS SECTION LOCATIONS
CROYDON ICE SITE, BUCKS COUNTY, PA

AR300365

Figure 3-2
(see back pocket)

AR300366

Underneath the unconsolidated alluvium is an extensively decomposed schist. The contact between the alluvial deposit and the clay/saprolite layer is unconformable and very irregular. The clay/saprolite is transitional from white-tan clay with trace mica to tan-brown clay with decomposed cobbles of schist to grey, very micaceous, weathered schist with greater penetration into the weathered formation.

The clay/saprolite layer is extensive throughout the study area and forms an impermeable boundary for the unconfined aquifer. The thickness of this layer was not determined, but soil borings penetrated up to 30 feet of the saprolite. Extensive coring of the saprolite layer was conducted south of the study area (south of River Road) by Rohm & Haas Company (BCM, 1986a).

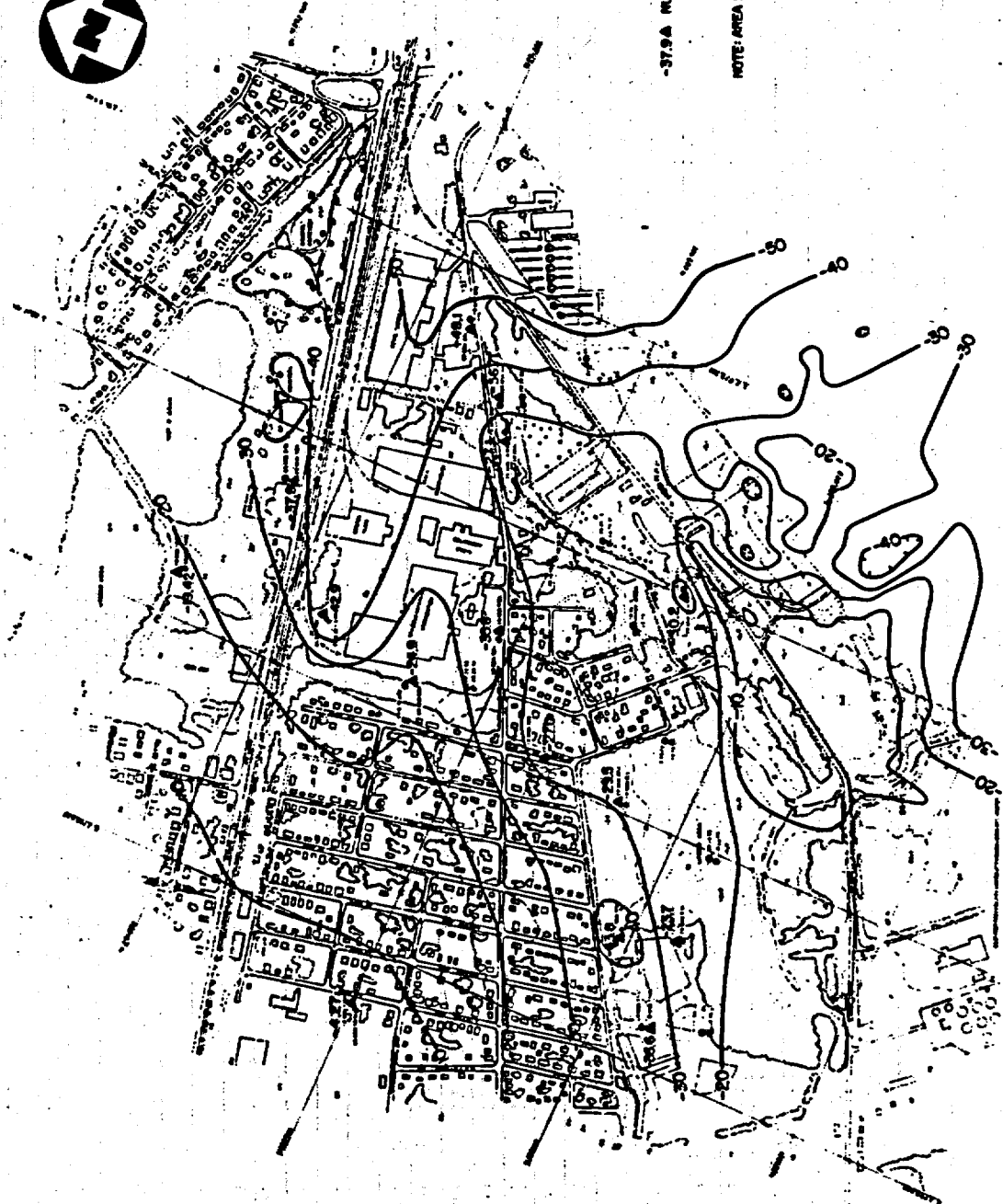
Figure 3-3 is a contour map of the top of the clay/saprolite layer. The area bounded by State Road and River Road is a depression in the saprolite surface. The elevation of the saprolite surface is high along River Road and at monitoring well locations CR-MW12 and CR-MW13 at the northern boundary of the site area.

3.4.3 Static Water Levels and Groundwater Flow

Static water-level measurements were collected on January 6, January 9, February 29, and March 25, 1988 (Table 3-1). Measurements were also taken following the construction of the monitoring wells. Water-level data was not obtained from seven wells on January 6 because continuous recorders in place on the wells inhibited the measurement, and from four wells on January 9 due to time constraints. Static water levels were taken at all REM III wells, and at 15 Rohm & Haas wells on February 29 (2 Rohm & Haas well-cluster locations could not be found). Monitoring-well locations measured on March 25 were selected to better define the groundwater flow system around the East Branch of Hog Run Creek. This round included water-level measurements at additional Rohm & Haas wells and at an additional staff gauge, which was added near monitoring well location CR-MW14.

Three staff gauges were installed during the hydrogeologic investigation. Staff gauge No. 2 was vandalized prior to surveying and could not be located by the subcontract surveyors. Access to staff gauge No. 3 was prohibited during field activities on February 29, 1988. An additional staff gauge (No. 4) was installed near monitoring well location CR-MW14 to better define the groundwater flow system along the East Branch of Hog Run Creek.

Potentiometric surface maps were prepared with static water-level data collected on February 29 and on March 25. Both shallow and deep flow systems were mapped (see **AP908367** through 3-7). Figures 3-4 and 3-5 show the potentiometric surface for the shallow and the deep wells on February 29, 1988.



LEGEND

-37.9A NUS MONTING WELLS AND ELEVATION OF TOP OF SAPROLITE

NOTE: AREA SOUTH / SOUTHEAST OF RIVER ROAD MAPPED BY DCA, 1986

FIGURE 3-3



**CONTOUR OF TOP OF SAPROLITE
CROYDON ICE SITE, BUCKS COUNTY, PA**



AR300368

TABLE 3-1

WATER-LEVEL ELEVATIONS
CROYDON TCE SITE

Monitoring Well	Date Measured									
	3-25-88	2-29-88	1-9-88	1-6-88	12-5-87	12-4-87	11-10-87	11-6-87	11-5-87	
CR-MW01(S)	13.41	15.21	12.80	S.R.(1)						
CR-MW01(D)	13.42	15.17	12.78	12.81			11.15			
CR-MW02(S)	14.67	15.00		12.71						
CR-MW02(D)	14.23	14.97		12.69						
CR-MW03(S)		12.55	10.96	S.R.(1)						
CR-MW03(D)		12.54	10.73	10.75						
CR-MW04(S)	12.06	12.39	11.05	11.09		11.30		11.15		
CR-MW04(D)	12.17	12.66	11.07	11.04				11.09		
CR-MW05(S)	12.28	12.87	11.12	11.19						
CR-MW05(D)	12.33	12.90	11.19	11.26						
CR-MW06(S)	13.33	14.04	11.91	11.94				12.17		
CR-MW06(D)	13.32	14.02	11.92	11.89				12.16		
CR-MW07(S)	12.14	12.87	10.90	10.99	11.16				11.08	
CR-MW07(D)	12.04	12.83	10.93	11.18					11.12	
CR-MW08(S)		12.07	10.34	10.41						
CR-MW08(D)		12.10	10.37	10.43						
CR-MW09(S)		11.36	9.80	S.R.(1)					9.99	
CR-MW09(D)		11.33	9.80	S.R.(1)					9.95	
CR-MW10(D)		11.73	10.04	10.12					10.21	
CR-MW11(S)		11.27	9.66	9.75					9.88	
CR-MW11(D)		11.25	9.64	9.76					9.83	
CR-MW12(S)		14.75	12.41	S.R.(1)						
CR-MW12(D)		14.84	12.46	12.53						
CR-MW13(S)		17.17		14.47	14.99					
CR-MW13(D)		17.18		14.50	14.93					
CR-MW14(S)	11.84	12.14	11.04	11.06						
CR-MW14(D)	12.06	12.49	11.04	11.03						
CR-MW15(S)	8.29	8.55	8.27	S.R.(1)				8.30		
CR-MW15(D)	9.23	9.49	8.62	S.R.(1)				8.57		

TABLE 3-1
WATER-LEVEL ELEVATIONS
CROYDON TCE SITE
PAGE TWO

Staff Gauges	Date Measured							
	3-25-88	2-29-88	1-9-88	1-6-88	12-5-87	12-4-87	11-10-87	11-5-87
S.G. #1	7.80	7.91	7.71	7.3				
S.G. #2		Vandalized(2)						
S.G. #3		No Access(3)	3.72	3.85				
S.G. #4	7.98							

Monitoring Well	Date Measured							
	3-25-88	2-29-88	1-9-88	1-6-88	12-5-87	12-4-87	11-10-87	11-5-87
CR-MW13(S)		17.17		14.47	14.99			
CR-MW13(D)		17.18		14.50	14.93			
CR-MW14(S)	11.84	12.14	11.04	11.06				
CR-MW14(D)	12.06	12.49	11.04	11.03				
CR-MW15(S)	8.29	8.55	8.27	S.R.(1)				8.30
CR-MW15(D)	9.23	9.49	8.62	S.R.(1)				8.57

Rohm & Haas Monitoring Well	Date Measured							
	3-25-88	2-29-88	1-9-88	1-6-88	12-5-87	12-4-87	11-10-87	11-5-87
CR-18-30	11.37	11.81						
CR-18-55	11.52	12.06						
CR-19-15	9.87	10.07						
CR-19-37	11.56	11.96						
LP-13-18	10.74	11.22						
LP-13-43	11.36	11.99						
CR-22	10.29							
CR-21-50	10.44							
CR-21-27	10.62							
CR-21-17	10.50							
CR-21-38	10.76							

TABLE 3-1
WATER-LEVEL ELEVATIONS
CROYDON TCE SITE
PAGE THREE

Rohm & Haas Monitoring Well	Date Measured									
	3-25-88	2-29-88	1-9-88	1-6-88	12-5-87	12-4-87	11-10-87	11-6-87	11-5-87	
LP-14-20		11.75								
LP-15-26		10.97								
LP-15-37		10.87								
CR-23-53		13.61								
CR-23-32		13.59								
CR-24-7		N.L. (4)								
CR-24-16		N.L. (4)								
CR-25-13	9.36	N.L. (4)								
CR-25-34	L.R. (5)	N.L. (4)								
CR-26-19		11.16								
CR-26-38		11.38								
CR-27-18		12.01								
CR-27-38		12.25								

- (1) S.R. = Stevens Recorder inhibited water level measurement.
 (2) Vandalized = Staff gauge position was moved prior to surveying.
 (3) No Access = Gate entrance to landfill was locked.
 (4) N.L. = Monitoring well could not be located.
 (5) L.R. = Lock rusted shut.

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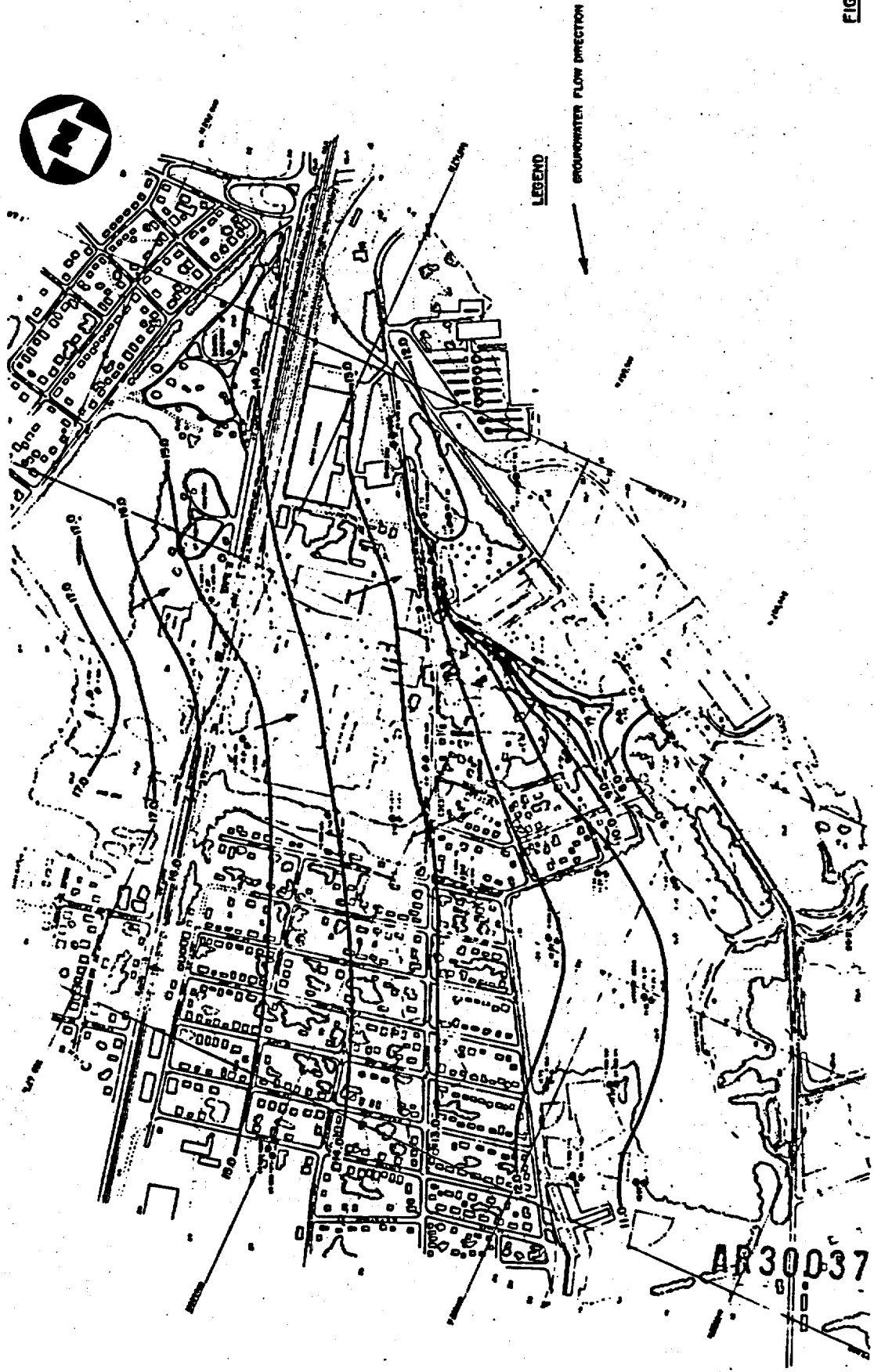


FIGURE 3-4



POTENTOMETRIC SURFACE MAP-SHALLOW WELLS (2/29/88)
 CROYDON TCE SITE, BUCKS COUNTY, PA

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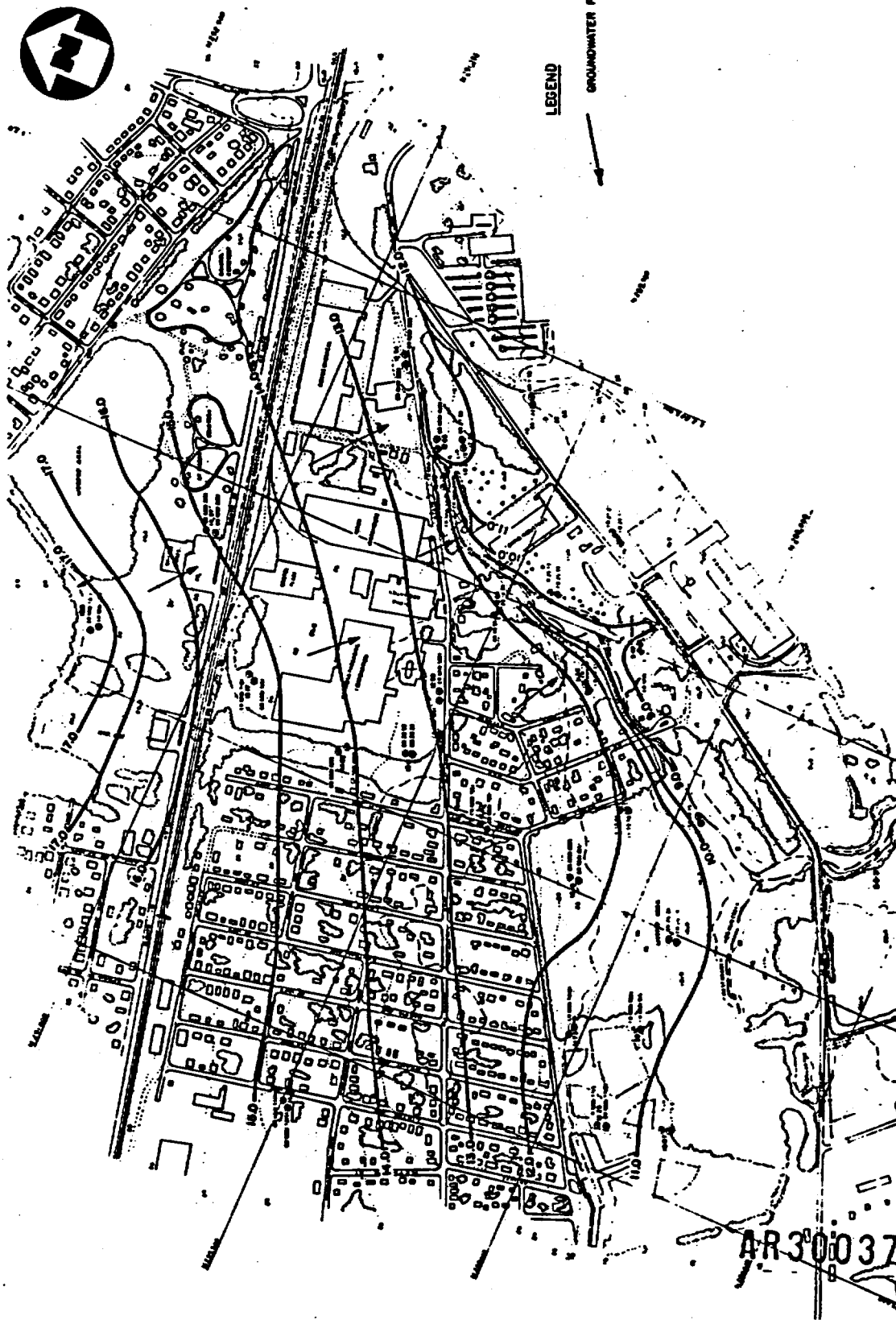


FIGURE 3-5



POTENTIOMETRIC SURFACE MAP-DEEP WELLS (2/29/88)
CROYDON TCE SITE, BUCKS COUNTY, PA

AR 300373

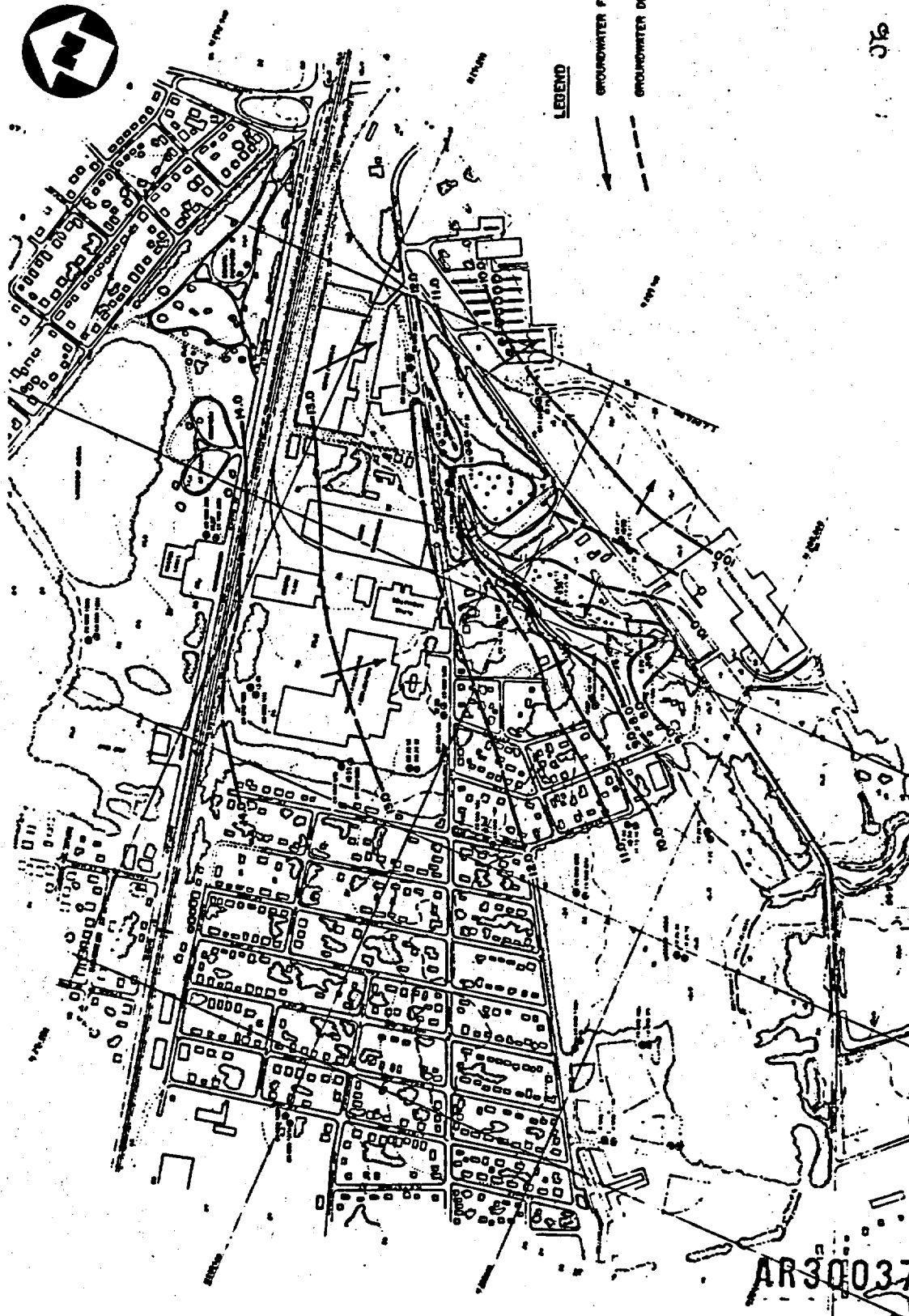
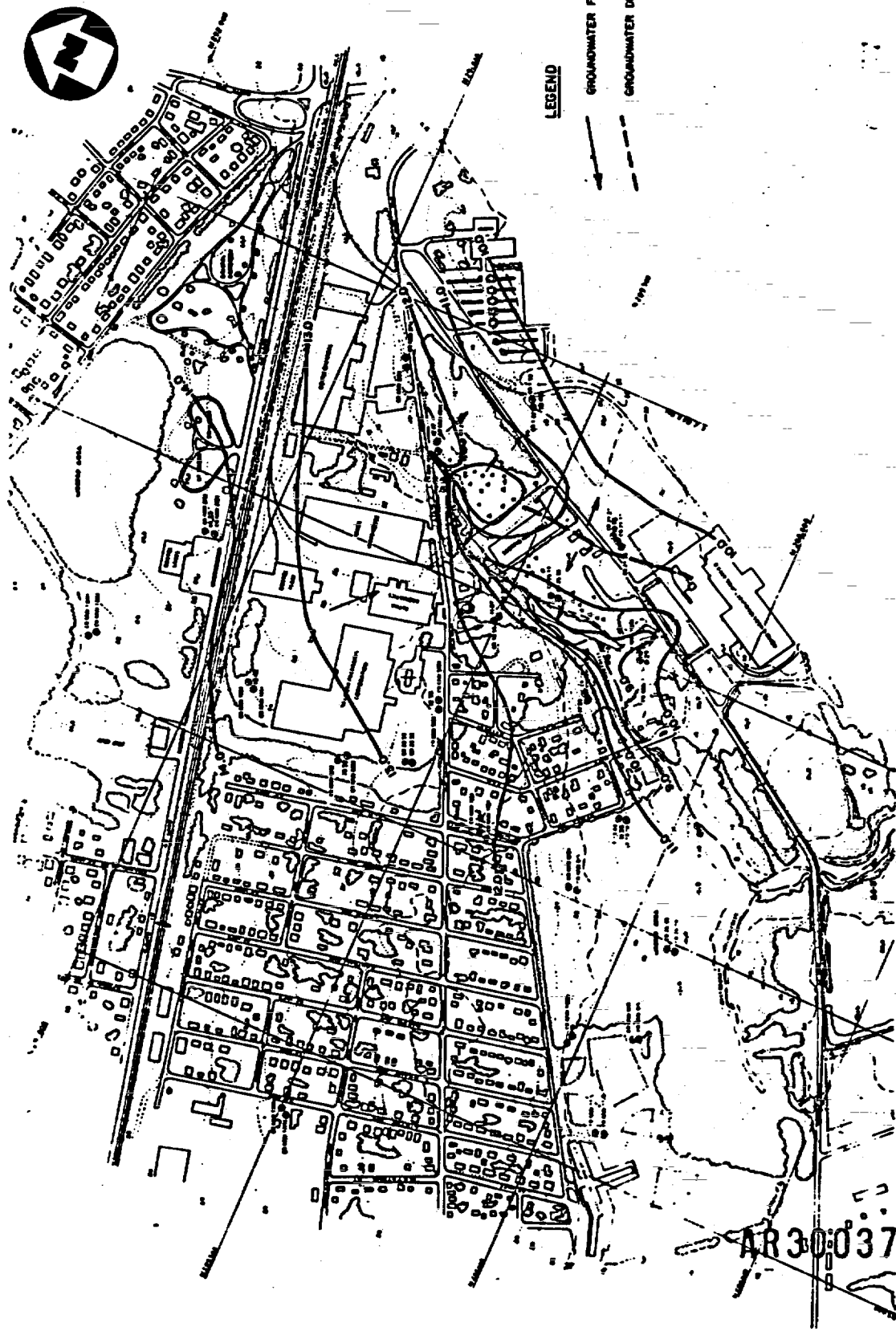


FIGURE 3-6



POTENTIOMETRIC SURFACE MAP-SHALLOW WELLS (3/25/88)
CROYDON ICE SITE, BUCKS COUNTY, PA

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LEGEND

GROUNDWATER FLOW DIRECTION

GROUNDWATER DIVIDE

FIGURE 3-7



POTENTIOMETRIC SURFACE MAP-DEEP WELLS (3/25/88)
CROYDON TCE SITE, BUCKS COUNTY, PA

AR300375

Both potentiometric surface maps show an overall regional groundwater flow to the southeast. Since ground flow directions south of the East Branch of Hog Run Creek were uncertain, additional water levels were taken on March 25, 1988. The potentiometric surface maps for March 25 again show the regional groundwater flow direction toward the southeast with a local flow system present at Hog Run Creek. Isocontours of hydraulic head for both the shallow and deep flow system indicate groundwater flow directions are toward Hog Run Creek, and the hydraulic head difference at well clusters indicates an upward flow component.

In the local flow system, groundwater is flowing in the opposite direction of the regional flow, along the south side of the East Branch of Hog Run Creek. Since groundwater flow directions south of River Road are to the southeast, there appears to be a groundwater divide in the vicinity of River Road. The position of the divide, shown on Figure 3-6, is only approximate and will need to be defined in the Phase II Remedial Investigation.

Another local flow system may also be present at the intermittent stream located just north of Potential Source Area No. 1. This system will be investigated during the Phase II Remedial Investigation.

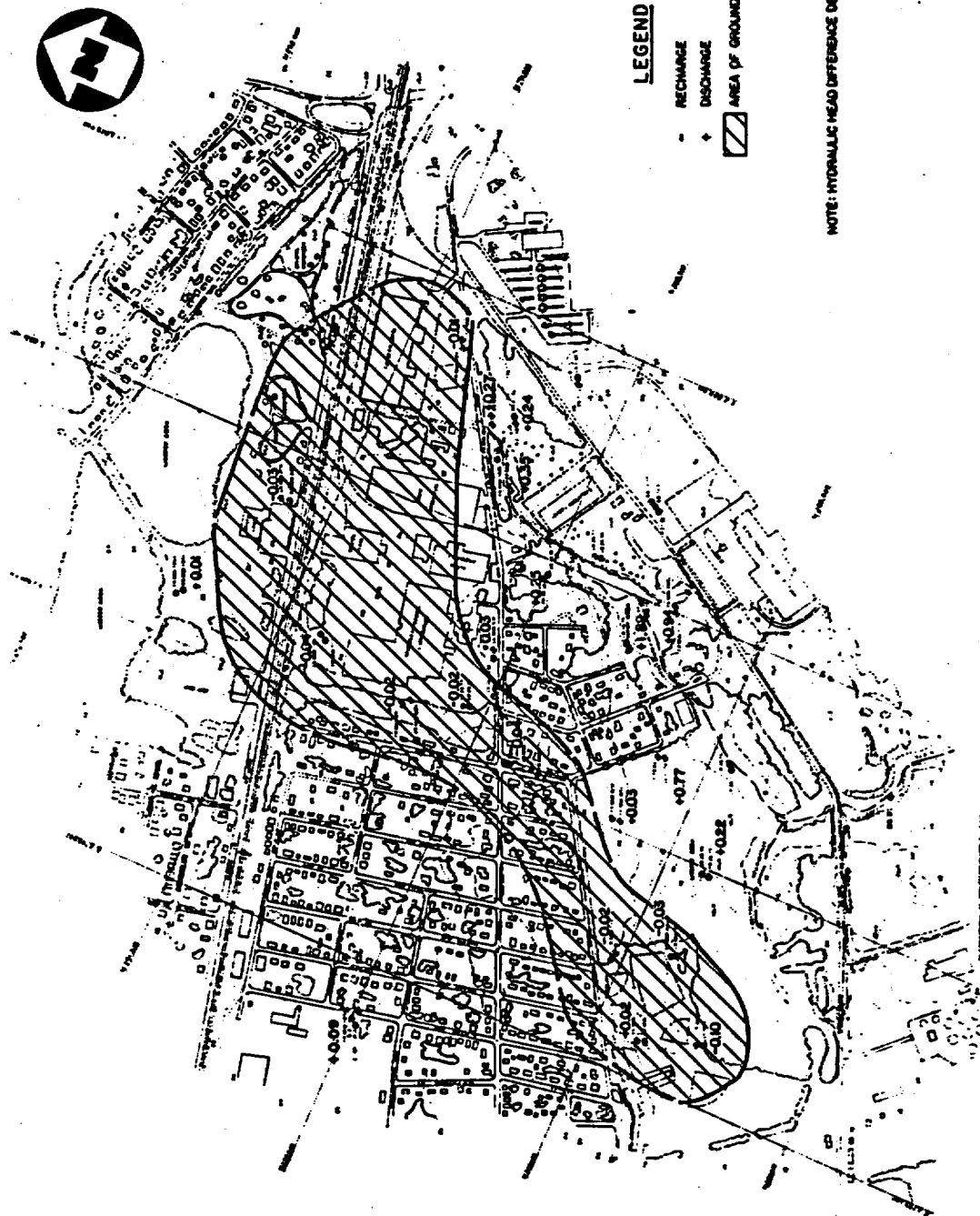
Hydraulic head differences between the shallow wells and deep wells were calculated to determine recharge and discharge areas. Figure 3-8 shows the area of recharge as determined from static water levels taken on February 29, 1988. Groundwater recharge occurs when the hydraulic head is higher in the shallow well than in the deep well and groundwater discharge occurs when the hydraulic head in the shallow well is lower than in the deep well.

Depths to the water table ranged from ground level to a depth of 18 feet. The average depth is approximately 8.7 feet. Water-level measurements were taken in the fall, winter, and spring. Seasonal fluctuations in the water levels are evident. Water-level elevations were lower when the monitoring wells were installed than they were in early 1988 (January through March).

3.4.4 Aquifer Tests

In-situ hydraulic conductivity tests at the Croydon TCE Site were conducted at all newly installed REM III monitoring wells and at a few existing Rohm & Haas wells. Solid-slug tests were conducted on the 2-inch REM III wells, whereas bailer-slug removal was used at the 4-inch Rohm & Haas wells.

A slug test is a type of aquifer test performed to determine the hydraulic conductivity of the formation at the screened interval of the monitoring well. This test may either be performed by recording the falling water level (falling-head test) or by recording the recovering water level (rising-head test). Rising head tests were conducted at deep and shallow monitoring wells;



LEGEND

- RECHARGE
- + DISCHARGE
- ▨ AREA OF GROUNDWATER RECHARGE

NOTE: HYDRAULIC HEAD DIFFERENCE DETERMINED FOR 2/29/88



FIGURE 3-8



**ZONES OF GROUNDWATER RECHARGE AND DISCHARGE
CROYDON TCE SITE, BUCKS COUNTY, PA**

AR300377

falling head tests were conducted only at deep monitoring wells. Procedures for conducting slug tests entailed rapidly lowering an 8-foot-long, 1-inch-diameter, solid section of PVC down the monitoring well. This procedure instantaneously displaces water inside the well casing. Water-level measurements are then recorded as the water level drops back to its equilibrium level. This is known as a falling-head test. After the water level has stabilized, the rising-head test is conducted. This entails rapidly removing the slug and again recording the water level as it rises back to equilibrium.

Water-level measurements were collected with a pressure transducer and recorded by a data logger (HERMIT SE1000B). Slug test data appears in Appendix G. The Bouwer and Rice Method (1976) of slug test interpretation for determining hydraulic conductivity in an unconfined aquifer with completely or partially penetrating wells was used for the data interpretation. Calculations, well construction specifics, and drawdown plots appear in Appendix H.

Table 3-2 lists the hydraulic conductivity (K) for each well. Hydraulic conductivities ranged from 1.20×10^{-5} cm/sec to 2.36×10^{-2} cm/sec. The lowest values were measured at CR-MW01(D), CR-MW07(D), CR-MW15(D), and CR-MW04(S). These wells had hydraulic conductivity ranges of 10^{-5} cm/sec to 10^{-4} cm/sec. The three deep wells are apparently screened in the clay/saprolite layer. These wells were not intentionally set in a low-permeability zone. Split-spoon sample recovery indicated coarse material at these depths. A clay is present at the screened material of CR-MW04(S).

The average hydraulic conductivity (omitting the four low values described above) of the unconfined aquifer is 8.18×10^{-3} cm/sec or 23.18 ft/day. At 10 of the well locations, the permeability of the shallow well is greater than the permeability of the corresponding deep well. The other five well clusters had nearly identical hydraulic conductivity values between wells at a given cluster. There does not appear to be any spatial correlation to this fact.

Hydraulic gradients calculated across the recharge area ranged from 0.0047 ft/ft to 0.0060 ft/ft. Hydraulic gradients measured in the shallow monitoring wells did not vary significantly from those in the deep wells.

The groundwater flow rate can be determined by the Darcy's Law using an average hydraulic gradient of 0.005 ft/ft and an average hydraulic conductivity of 23.18 ft/day:

AR300378

TABLE 3-2
HYDRAULIC CONDUCTIVITY VALUES
CROYDON TCE SITE

Well No.	K (cm/sec)	K (ft/min)	K (ft/day)
CR-MW01(S)	1.12×10^{-2}	2.20×10^{-2}	31.68
CR-MW01(D)	1.20×10^{-5}	2.36×10^{-5}	0.03
CR-MW02(S)	2.36×10^{-2}	4.64×10^{-2}	66.82
CR-MW02(D)	2.57×10^{-3}	5.06×10^{-3}	7.28
CR-MW03(S)	5.18×10^{-3}	1.02×10^{-2}	14.69
CR-MW03(D)	5.49×10^{-3}	1.08×10^{-2}	15.55
CR-MW04(S)	5.81×10^{-5}	1.14×10^{-4}	0.16
CR-MW04(D)	1.03×10^{-3}	2.04×10^{-3}	2.97
CR-MW05(S)	1.50×10^{-2}	2.95×10^{-2}	42.48
CR-MW05(D)	2.63×10^{-3}	5.18×10^{-3}	7.46
CR-MW06(S)	1.34×10^{-2}	2.63×10^{-2}	37.87
CR-MW06(D)	6.76×10^{-4}	1.33×10^{-3}	1.92
CR-MW07(S)	2.26×10^{-2}	4.45×10^{-2}	64.08
CR-MW07(D)	7.32×10^{-5}	1.44×10^{-4}	0.21
CR-MW08(S)	1.71×10^{-2}	3.36×10^{-2}	48.38
CR-MW08(D)	1.74×10^{-2}	3.42×10^{-2}	49.25
CR-MW09(S)	1.52×10^{-2}	3.00×10^{-2}	43.20
CR-MW09(D)	5.14×10^{-3}	1.01×10^{-2}	14.54
LF-14-20	1.13×10^{-2}	2.22×10^{-2}	31.97
CR-MW10(D)	2.65×10^{-3}	5.22×10^{-3}	7.52
CR-MW11(S)	2.82×10^{-3}	5.55×10^{-3}	7.99
CR-MW11(D)	2.35×10^{-3}	4.62×10^{-3}	6.65
CR-MW12(S)	1.09×10^{-2}	2.15×10^{-2}	30.96
CR-MW12(D)	3.22×10^{-3}	6.33×10^{-3}	9.12
CR-MW13(S)	3.10×10^{-3}	6.11×10^{-3}	8.80
CR-MW13(D)	4.58×10^{-3}	9.02×10^{-3}	12.99
CR-MW14(S)	1.01×10^{-2}	1.98×10^{-2}	28.51
CR-MW14(D)	3.54×10^{-3}	6.96×10^{-3}	10.02
CR-MW15(S)	6.76×10^{-3}	1.33×10^{-2}	19.15
CR-MW15(D)	2.40×10^{-4}	4.73×10^{-4}	0.68
LF-13-43	9.60×10^{-3}	1.89×10^{-2}	27.22

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$$V = k(dh/dl)/N_e$$

Where:

dh/dl = Hydraulic gradient in ft/ft (0.005)

V = Groundwater flow rate

k = Hydraulic conductivity in ft/day (23.18)

N_e = Effective porosity (assumed to be 30%)

$$V = (23.18 \text{ ft/day})(0.005 \text{ ft/ft})/0.30$$

$$V = 0.39 \text{ ft/day}$$

$$V = 141 \text{ ft/year}$$

3.4.5 Groundwater - Tidal Fluctuation

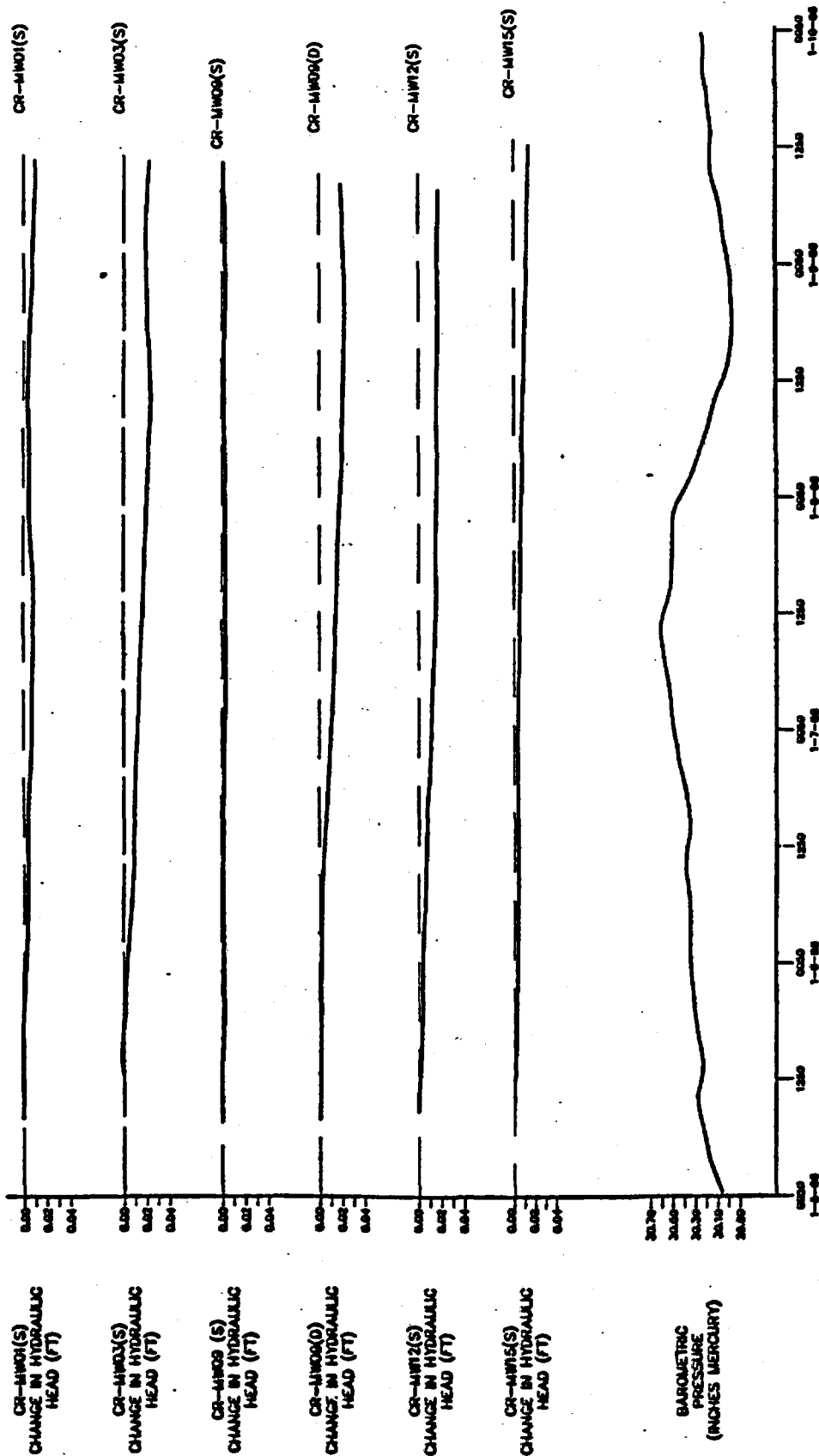
Continuous water-level monitoring was conducted to assess the impact of tidal fluctuation on the water table at five monitoring-well clusters. Two of these well clusters had a continuous recorder on both the shallow and the deep well, and the other three clusters had a continuous recorder on the shallow monitoring well. The monitoring wells used in the study were CR-MW01(S), CR-MW03(S), CR-MW09(S), CR-MW09(D), CR-MW12(S), CR-MW15(S), and CR-MW15(D). The water level inside the casing at CR-MW15(D) froze around the float due to the extremely cold weather and because of the artesian conditions at this location.

Figure 3-9 depicts the change in water levels and barometric pressure over a 5-day period. The maximum change in hydraulic head of -0.03 ft was measured at CR-MW03(S). The minor fluctuations on the hydrograph are believed to be due to barometric pressure changes and seasonal trends. The hydraulic head change is not related to tidal fluctuations in the Delaware River and the lower reaches of Hog Run Creek (see Section 3.3). Groundwater level fluctuations due to tides extends approximately 1,100-1,600 feet in from the Delaware River (BCM, 1988). The hydrographs and barometric graphs were compiled from data recorded on strip charts and from barometric pressure data recorded at the Philadelphia International Airport Weather Station (see Appendix I). The weather station is located approximately 21 miles southwest of the study area.

3.5 CLIMATOLOGY

The Appalachian Mountains to the west and the Atlantic Ocean to the east have a moderating effect on climate. Periods of very high or very low temperatures seldom last for more than 3 or 4 days. Temperatures below zero or above 100 degrees are a rarity. On occasion, the area becomes engulfed with maritime air during the summer months, and high humidity adds to the discomfort of seasonably warm temperatures (NOAA, 1987).

As shown on Table 3-3, the record mean monthly temperature for the period 1957 to 1986 ranges from 32.6°F (January) to 76.6°F (July). Data shown on Table 3-3 represent the Philadelphia Airport Station, which is located approximately 21 miles southwest of the Croydon TCE Site.



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FIGURE 3-9
NUS CORPORATION

HYDROGRAPHS AND BAROMETRIC PRESSURE RECORDED
DURING TIDAL FLUCTUATION STUDY
CROYDON TCE SITE, BUCKS COUNTY, PA

TABLE 3-3

30-YEAR PRECIPITATION AND TEMPERATURE DATA
CROYDON TCE SITE

PRECIPITATION (inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1957	1.67	2.81	3.24	4.22	1.21	2.41	0.64	3.38	3.10	2.35	2.48	4.49	32.20
1958	2.53	4.64	4.97	4.19	3.65	5.13	5.98	8.20	2.55	3.85	2.05	1.13	47.87
1959	2.03	1.60	2.55	2.26	0.80	5.28	7.48	3.73	1.33	3.41	3.29	3.62	38.37
1960	3.11	3.44	2.46	2.82	3.65	0.71	6.52	3.19	8.78	2.79	1.92	3.16	41.15
1961	3.16	3.13	5.17	4.82	3.38	2.45	5.96	3.42	2.41	1.83	2.04	2.78	41.05
1962	2.95	3.51	3.91	3.69	1.85	7.40	2.30	6.58	2.77	0.95	4.60	2.11	42.62
1963	2.37	2.19	3.94	1.13	1.06	2.88	3.13	3.35	6.44	0.09	6.67	1.76	34.95
1964	3.92	2.83	1.94	5.27	0.47	0.21	3.83	0.49	2.42	1.73	1.64	5.13	29.88
1965	2.35	2.18	3.19	2.33	1.23	2.85	3.22	4.05	3.02	2.02	1.55	1.95	29.34
1966	2.62	4.35	0.68	4.35	2.95	0.41	2.35	1.63	8.70	5.12	2.36	4.33	40.00
1967	1.67	1.82	4.53	2.17	3.49	4.12	7.11	7.08	2.96	2.00	1.99	5.88	44.82
1968	2.50	1.45	4.98	1.57	5.17	5.89	2.00	1.24	0.44	3.15	4.17	2.54	35.45
1969	1.57	1.88	1.92	1.68	3.30	7.31	8.33	2.66	4.38	1.13	1.97	7.23	43.36
1970	0.74	2.08	3.83	6.12	2.57	4.60	2.75	3.99	0.82	3.66	4.71	3.27	39.14
1971	2.13	5.43	2.58	1.84	4.10	1.01	4.84	9.61	5.83	3.84	5.37	1.21	47.79
1972	2.34	5.09	2.69	4.08	4.11	5.79	2.62	3.76	1.12	3.77	9.36	5.20	49.63
1973	3.93	2.96	3.52	6.68	4.14	7.88	2.39	3.03	3.39	2.16	0.64	6.34	46.06
1974	2.95	2.14	4.91	2.77	3.21	4.43	2.08	3.83	4.68	1.93	0.81	4.04	37.78
1975	4.00	2.91	4.88	2.97	4.99	1.57	6.32	2.21	7.21	3.24	3.14	2.89	52.13
1976	4.50	1.66	2.38	2.06	4.35	3.42	4.04	2.17	2.44	4.30	0.32	1.63	33.27
1977	2.61	1.33	4.19	5.59	0.70	5.33	1.47	8.70	3.44	3.11	7.76	5.19	49.42
1978	8.86	1.35	4.31	1.76	6.01	1.75	5.27	6.04	1.59	1.20	2.20	5.61	45.95
1979	8.74	6.44	2.43	4.08	3.98	4.34	3.95	5.95	4.89	3.84	2.48	5.67	52.79
1980	2.27	0.96	7.01	4.79	3.22	1.73	6.58	0.80	2.79	5.03	2.83	6.77	38.80
1981	0.50	2.94	1.61	3.60	4.52	4.40	4.54	5.11	2.83	2.68	0.95	4.14	37.83
1982	4.45	3.16	2.66	6.06	4.47	5.76	1.94	2.20	2.32	1.94	3.67	1.80	40.43
1983	2.81	3.53	6.70	8.12	7.03	2.75	0.88	2.57	3.45	3.99	5.71	7.37	54.41
1984	2.22	2.81	6.14	4.25	6.87	2.85	6.99	3.28	1.96	2.56	1.56	2.17	43.66
1985	1.55	2.44	1.95	0.52	4.99	1.88	4.66	2.82	5.78	1.54	6.39	5.98	35.20
1986	4.13	3.38	1.25	4.46	0.70	1.99	4.10	3.70	2.33	2.22	6.27	5.89	40.42
Record Mean	3.23	3.08	3.54	3.37	3.42	3.62	4.09	4.45	3.38	2.80	3.15	3.22	41.34

AVERAGE TEMPERATURE (deg F)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1957	39.2	37.4	42.3	54.2	63.5	74.9	76.6	73.2	65.2	54.1	47.8	39.4	55.1
1958	31.8	28.2	39.9	54.2	61.2	67.6	76.4	73.4	65.9	55.7	46.6	29.4	52.6
1959	31.6	33.3	41.5	54.8	66.4	72.2	75.9	76.5	70.8	60.1	45.2	38.2	55.5
1960	34.2	35.4	32.7	56.7	66.2	70.6	73.3	74.5	67.3	54.8	45.5	27.6	52.8
1961	25.0	34.0	43.7	49.8	58.6	69.9	75.6	73.5	71.5	55.7	45.2	31.3	52.7
1962	30.0	30.4	40.5	52.0	64.1	71.7	72.0	72.0	63.1	56.3	42.1	31.0	52.1
1963	27.8	26.5	42.9	52.5	60.2	70.4	76.0	71.2	62.8	57.1	48.0	27.9	51.9
1964	33.0	31.8	42.7	50.8	65.1	72.4	75.6	72.2	67.2	52.6	47.1	31.5	54.1
1965	29.2	33.7	37.6	49.0	65.9	72.0	74.1	73.3	69.2	53.7	44.2	35.9	53.0
1966	29.1	31.5	42.8	47.8	59.9	72.1	77.9	74.8	65.2	53.1	45.8	35.5	53.0
1967	36.0	29.0	38.5	51.7	55.9	72.1	76.6	75.1	67.0	56.8	42.8	38.5	53.3
1968	28.9	30.4	44.4	54.6	63.7	71.2	77.1	77.8	69.4	58.1	45.6	32.2	54.1
1969	28.8	32.0	39.7	55.9	64.6	73.4	75.1	75.2	67.2	55.0	44.4	33.5	53.8
1970	24.9	33.1	38.3	51.5	64.9	71.8	76.9	76.7	72.0	60.1	48.2	35.8	54.5
1971	27.8	36.1	40.7	51.6	60.9	74.3	77.4	75.3	71.6	63.5	46.1	31.6	55.6
1972	35.1	32.4	40.7	49.7	63.6	68.7	77.1	76.0	69.2	52.7	43.6	39.9	54.1
1973	34.4	33.6	47.2	53.4	60.3	74.6	77.9	78.8	70.7	59.2	48.0	38.6	56.4
1974	35.9	31.7	43.3	55.8	62.4	70.3	76.9	76.8	68.1	54.8	48.8	39.4	55.3
1975	37.3	35.8	41.3	49.7	66.6	72.2	76.6	77.1	66.6	61.2	52.1	36.9	56.1
1976	28.7	40.9	46.3	56.6	62.7	75.2	75.3	74.6	67.3	52.5	39.9	32.3	54.2
1977	20.0	33.6	48.8	57.2	65.8	68.6	77.8	76.2	69.9	54.2	46.4	32.6	54.3
1978	28.0	24.7	39.0	50.6	61.4	72.6	75.6	79.2	68.5	55.5	47.9	38.6	53.5
1979	32.3	27.0	47.0	52.3	66.4	69.1	76.2	75.5	68.5	54.9	50.1	38.2	54.5
1980	31.8	29.7	40.3	54.7	65.4	70.6	78.8	80.0	72.2	54.9	43.2	32.5	54.5
1981	25.3	37.9	40.0	54.7	62.6	73.0	76.9	74.9	66.8	53.1	45.6	34.6	53.7
1982	24.7	34.4	41.7	50.2	65.9	68.7	76.9	73.5	67.6	56.9	48.4	31.3	54.2
1983	34.1	34.0	43.7	51.0	62.1	72.0	77.9	77.1	69.0	56.6	46.7	32.9	54.8
1984	28.2	38.7	39.5	50.0	60.2	73.0	73.9	75.2	64.7	51.2	41.4	31.9	53.8
1985	27.3	35.3	44.6	55.5	64.5	68.8	75.4	74.1	69.1	59.3	51.3	33.3	54.9
1986	32.8	32.1	44.5	53.3	66.8	73.8	78.1	74.0	68.3	57.8	44.5	31.3	55.3
Record Mean	32.6	33.7	41.8	52.3	63.0	71.8	76.6	74.8	68.4	57.3	46.2	36.1	54.6
Max	39.7	41.2	50.1	61.7	72.7	81.1	85.4	83.2	77.0	66.0	53.9	43.2	62.9
Min	25.9	26.2	33.4	42.9	53.4	62.4	67.8	66.3	59.8	48.6	38.5	28.1	46.2

Note: Data collected from the Philadelphia International Airport (approximately 21 miles southeast of the Croydon TCE Site).

Source: NOAA, 1987.

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Precipitation is fairly evenly distributed throughout the year with maximum amounts during the late summer months. Much of the summer rainfall is from local thunderstorms. Snowfall amounts are often considerably larger in the northern suburbs than in the central and southern parts of the city. Single storms of 10 inches or more occur about every 5 years (NOAA, 1987).

As shown on Table 3-3, the record mean monthly precipitation ranges from 2.80 inches (October) to 4.45 inches (August) for the period 1957 through 1986.

The prevailing wind direction for the summer months is from the southwest, whereas northwesterly winds prevail during the winter. The annual prevailing direction is from the west-southwest. Destructive velocities are comparatively rare and occur mostly in gustiness during summer thunderstorms. High winds occurring in the winter months, as a rule, come with the advance of cold air after the passage of a deep, low-pressure system. Only rarely have hurricanes in the vicinity caused widespread damage, primarily because of flooding (NOAA, 1987).

3.6 LAND USE

The study area is located in the southernmost portion of Bristol Township, Bucks County, Pennsylvania. Within this area, which is estimated to be approximately 3.5 square miles, are several residential communities, commercial businesses, and small- to large-scale industrial facilities. Most of the commercial-type businesses are located along U.S. Route 13 and State Road. The Penn Central Railroad runs parallel with U.S. Route 13 through the study area. At present, most of the railroad traffic is associated with commuter transportation. Industrial operations are primarily situated between River Road and U.S. Route 13 in the easternmost portion of the study area. The remaining area is mostly residential. The largest tract of unused land can be found between River Road and Summit Avenue. This area, which is heavily overgrown with vegetation and wooded, is owned by the Rohm & Haas Company.

The northern portion of the study area (i.e., north of U.S. Route 13) is primarily residential and is made up of the following communities: Croydon Acres, Croydon Heights, Belardy, Maple Shade, West Bristol, and Rockdale. Croydon is located in the southern portion (i.e., south of U.S. Route 13) of the study area. Over half of the Croydon area is residential. The remaining portion is either vacant land or is used for manufacturing. The industrial/manufacturing complexes are located in the easternmost portion of the study area between U.S. Route 13 and River Road. The major industries within this area are listed below:

- Coyne Chemical
- Gilbreath International Corporation
- Nakoosa Packaging (formerly Owens-Illinois)

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- Bristol Flare
- Alpha Aromatics

The largest industrial facility in the area is the Rohm & Haas Company. This facility extends from the landfill area (to the west) to Manufacturing Areas A and C, which are located east of Route 413 in Bristol, Pennsylvania. Manufacturing Area B is situated south of River Road nearest to the site. None of the Rohm & Haas manufacturing complexes are located within the study area.

Throughout the study area are a number of public and private schools, churches, and recreational areas. The largest recreational area is the Neshaminy State Park near the confluence of Neshaminy Creek and the Delaware River. Most of the park, however, is located outside the study area west of Neshaminy Creek. Recreational activities along the Delaware River are centered on boating and fishing. Numerous boat docks and slips can be seen from the mouth of Neshaminy Creek upstream to the U.S. Route 13 bridge. Other recreational areas are located near the Mary Devine School and the old Croydon School. The area adjacent to the Mary Devine School consists of several athletic fields, which are owned by the Rohm & Haas Company. This area is within the focused area of investigation, since historical photographs have indicated past activities that may be associated with land disturbance. Additionally, a local citizen alleges that Rohm & Haas Company placed fill material from its landfill to the area where the athletic fields are located. Rohm & Haas reported that no dumping of wastes has occurred on or near the Mary Devine School property or athletic fields (BCM, 1988).

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4.0 NATURE AND EXTENT OF CONTAMINATION

This section provides a description of the nature and extent of environmental contamination within the Croydon TCE Site study area. This section is based on validated analytical results obtained during the Phase I RI field investigation conducted October through January 1988. Included is a discussion of the types of contaminants found, the concentrations observed, and their occurrence and distribution within each environmental media sampled.

4.1 GROUNDWATER

4.1.1 Scope of Sampling and Analysis

Twenty-nine REM III monitoring wells, seventeen existing Rohm & Haas monitoring wells, and forty residential wells were sampled during the Phase I RI. Residential-well and monitoring-well sampling locations are shown on Figures 4-1 and 4-2, respectively.

The primary objectives of the monitoring-well sampling were to characterize the nature and extent of groundwater contamination in the southeastern portion of the study area and to identify potential source areas that may be contributing to groundwater contamination. Residential wells were sampled to characterize water quality throughout the Croydon TCE Site study area and to assess the potential public health risks associated with groundwater use.

All new and existing monitoring wells and all residential wells were analyzed for Target Compound List (TCL) volatile organics. Ten residential wells (RW30 through RW39) were analyzed for selected water chemistry parameters in addition to the TCL volatiles. Additionally, selected monitoring wells (LF-13-18, LF-13-43, LF-15-26, LF-15-37, MW3(S), MW3(D), MW5(S), MW5(D), MW13(S), and MW13(D) and selected residential wells (RW1 through RW8) were analyzed for TCL base-neutral acid (B/N/A) extractable organics, TCL pesticides/polychlorinated biphenyls (PCBs), Target Analyte List (TAL) inorganics, and cyanide.

The analytical results are provided in Appendix J.

4.1.2 Nature and Extent of Contamination

TCL organic and TAL inorganic compounds were detected in both monitoring wells and residential well samples collected within the site study area. Tables 4-1 through 4-3 list the organic and inorganic groundwater contaminants detected.

As indicated in these tables, the primary contamination in the monitoring-well and residential-well samples is due to volatile organic compounds. Within this group, chlorinated aromatic hydrocarbons constitute the largest proportions and widest occurrence. Of these compounds, the predominant contaminant is

Figures 4-1 and 4-2
(see back pocket)

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TABLE 4-1

ORGANIC AND INORGANIC CONSTITUENTS
DETECTED IN REM III MONITORING WELLS
CROYDON TCE SITE

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Benzene	0.4J	MW1(D)
1,1,1-Trichloroethane	160	MW15(S)
1,1,2-Trichloroethane	0.7J	MW15(D)
1,1-Dichloroethane	3J	MW15(D)
1,2-Dichloroethane	16J	MW8(D)
Tetrachloroethene	4.1J	MW5(D)
Trichloroethene	420	MW15(D)
1,1-Dichloroethene	75	MW15(D)
Chloroform	3.4J	MW7(D)
Bromodichloromethane	0.4J	MW5(S)
Cis-1,2-dichloroethane	0.1/J	MW15(S) MW15(D)
4,4-DDT	2J	MW5(S)
Aluminum	129,000/ND(2)	MW5(S)
Antimony	25/ND	MW5(S)
Arsenic	31/ND	MW13(S)
Barium	4,800/36	MW13(S)
Beryllium	45/ND	MW13(S)
Cadmium	5.2/ND	MW13(D)
Calcium	31,100/14,000	MW13(S)
Chromium	2,000/ND	MW13(S)
Cobalt	744/13	MW13(S)
Copper	1,780/ND	MW13(S)
Iron	257,000/ND	MW5(S)
Lead	68/ND	MW5(S)

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TABLE 4-1
ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN REM III MONITORING WELLS
CROYDON TCE SITE
PAGE TWO

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Magnesium	167,000/4,340	MW13(S)
Manganese	11,300/4,100	MW5(S)
Mercury	1.1/ND	MW13(S)
Nickel	1,690/ND	MW13(S)
Potassium	51,500/2,750	MW13(S)
Sodium	17,700/15,600	MW5(S)
Vanadium	1,650/ND	MW13(S)
Zinc	5,350/ND	MW13(S)
Ammonia (as N) (mg/l)	0.34	MW5(D)
Chloride (mg/l)	63.4	MW5(S)
Nitrite/Nitrate (as N) (mg/l)	0.14	MW13(S)
Sulfate (mg/l)	78.3	MW5(D)
TDS (mg/l)	1,300	MW13(S)
TSS (mg/l)	33,010	MW13(S)
BOD (mg/l)	122	MW13(S)
Alkalinity (CaCO ₃) (mg/l)	43.2	MW13(S)

Notes:

- (1) Results reported in µg/l unless otherwise noted.
- (2) Metal analyses reported as total metals/dissolved metals.
- J: Denotes reported value is estimated. Actual value may be higher or lower.
- ND: Not detected above instrument detection level.
- D: Denotes deep well
- S: Denotes shallow well

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TABLE 4-2

ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN ROHM & HAAS MONITORING WELLS
CROYDON TCE SITE

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Acetone	9.5J	CR-18-55(3)
2-Butanone	3.0J	CR-23-32
Trans-1,2-dichloroethene	4.6	CR-18-55
Cis-1,2-dichloroethene	1.4	CR-19-37
1,1,1-Trichloroethane	85	CR-26-38
1,1-Dichloroethane	1J	LF-13-18
Tetrachloroethene	2.3J	CR-19-37
Trichloroethene	300	CR-26-38
1,1-Dichloroethene	7.8	CR-19-37
Chloroform	8.9	LF-13-18
Chlorodibromomethane	0.3J	LF-15-26
Bis(2-ethylhexyl)phthalate	4J	LF-15-37
Dieldrin	0.3	LF-15-26
Aluminum	3,640J/ND(2)	LF-13-18
Barium	[105]/[84]	LF-13-18
Calcium	8,770/7,590	LF-13-18
Cobalt	[12]/ND	LF-13-18
Copper	39/26	LF-13-18
Iron	10,700/363J	LF-13-18
Lead	16J/[4.4]	LF-13-18
Magnesium	9,070/8,420	LF-13-18
Manganese	544/47	LF-13-18
Nickel	[17]/ND	LF-13-18
Potassium	[1,840]/[1,540]	LF-13-18
Sodium	13,400/12,900	LF-13-18

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TABLE 4-2
ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN ROHM & HAAS MONITORING WELLS
CROYDON TCE SITE
PAGE TWO

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Vanadium	[19]/ND	LF-13-18
Zinc	44/29	LF-13-18
Chloride	21	LF-13-18
Sulfate (mg/l)	39.5	LF-13-18
TDS (mg/l)	134	LF-13-18
TOC (mg/l)	1	LF-13-18
TSS (mg/l)	119	LF-13-18
BOD (mg/l)	<3	All wells sampled for BOD
Alkalinity (CaCO ₃) (mg/l)	8.7	LF-13-43-1

Notes:

- (1) Results reported in µg/l unless otherwise noted.
- (2) Metal analyses reported as total metals/dissolved metals.
- (3) Last number indicates well depth (e.g., CR-18-55 denotes well location No. 18---55 feet deep).
- J: Denotes reported value is estimated. Actual value may be higher or lower.
- ND: Not detected above instrument detection level.

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TABLE 4-3

ORGANIC AND INORGANIC CONSTITUENTS
DETECTED IN RESIDENTIAL WELLS
CROYDON TCE SITE

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Benzene	3.8	RW32
Ethylbenzene	16	RW-32
Chlorobenzene	0.02	RW32
1,1,1-Trichloroethane	75	RW34
1,1,2-Trichloroethane	0.05	RW34
1,1-Dichloroethane	3	RW33
1,2-Dichloroethane	3.3	RW18
Tetrachloroethene	4.3	RW34
Trichloroethene	97	RW21
Trans-1,2-dichloroethene	0.06	RW33
1,1-Dichloroethene	5.1J	RW34
Vinyl chloride	.19J	RW33
Carbon tetrachloride	0.24	RW35
Chloroform	1.2	RW1
Methylene chloride	100J	RW6
Bromodichloromethane	0.02	RW31
Butyl benzyl phthalate	8.2J	RW1
1,2-Dichlorobenzene	0.10	RW33
1,3-Dichlorobenzene	0.22	RW33
1,4-Dichlorobenzene	0.20	RW26
Aluminum	1,850J(2)	RW1
Barium	[106]L	RW4
Cadmium	[2,610]	RW7
Calcium	17,800	RW8
Copper	399	RW1
Iron	9,100J	RW1

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TABLE 4-3
ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN RESIDENTIAL WELLS
CROYDON TCE SITE
PAGE TWO

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
Lead	104K	RW1
Magnesium	11,000	RW4
Manganese	184	RW4
Mercury	0.2	RW1 RW7 RW2
Nickel	[16]	RW1
Potassium	[3,880]	RW2
Sodium	26,300	RW4
Vanadium	12	RW3
Zinc	385J	RW2
Ammonia (as N) (mg/l)	0.3	RW33
Chloride (mg/l)	49	RW38
Nitrite/Nitrate (as N) (mg/l)	0.26	RW35
Sulfate (mg/l)	86	RW39
TDS (mg/l)	320	RW35
TSS (mg/l)	415	RW32
BOD (mg/l)	14	RW32
Alkalinity (CaCO ₃) (mg/l)	71	RW30

Notes:

- (1) Results reported in µg/l unless otherwise noted.
- (2) Metal analyses for samples which are unfiltered: total metals
- ND: Not detected above instrument detection level.
- J: Denotes reported value is estimated. Actual value may be higher or lower.
- L: Denotes reported value may be biased low. Actual value may be higher.
- K: Denotes reported value may be biased high. Actual value may be lower.
- []: Brackets denote that the reported value is below the method detection level.

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trichloroethene. Trichloroethene (TCE) was detected above health-based ARARS (i.e., MCL is 5 µg/l) in 15 of the 46 monitoring wells and 8 of the 40 residential wells at concentration ranges of 5 µg/l to 420 µg/l, respectively. Other constituents frequently detected include the chlorinated aliphatic hydrocarbons (i.e., 1,1,1-trichloroethene, tetrachloroethene, 1,1-dichloroethane, 1,1-dichloroethene, and chloroform).

Several other organic compounds were detected in the groundwater at relatively low concentrations. These compounds include ketones (acetone and 2-butanone), aromatic hydrocarbons (i.e., benzene, xylenes, ethylbenzene, chlorobenzene, etc.) and halomethanes (e.g., methylene chloride). Relatively low levels of phthalate esters [diethyl phthalate, bis(2-ethylhexyl) phthalate] and several pesticides (4,4-DDT and dieldrin) were also identified in a limited number of the samples.

The occurrence and distribution of organic and inorganic contaminants in groundwater is illustrated in Figures 4-1 and 4-2. Based on the results of the residential well investigation, widespread groundwater contamination of the 3.5 square-mile study area does not seem to be present (see Figure 4-1). With the exception of residential well sample RW32, where trichloroethene was detected at a concentration of 5 µg/l, organic groundwater contamination is primarily limited to the southeastern portion of the study area.

Figures 4-1 and 4-2 suggest the presence of a TCE plume, which may be emanating north of U.S. Route 13 from one or two potential source areas (Potential Source Area No. 1 or No. 3b). Groundwater contamination extends from U.S. Route 13 (see residential well No. 34) to Hog Run Creek. The plume appears to be migrating from either Potential Source Area No. 1 or No. 3b (see Figures 4-1 and 4-2). The plume may be migrating to the south-southeast, in the direction of regional groundwater flow. The Phase II RI will attempt to assess this theory further. Based on an evaluation of the occurrence and distribution of groundwater contamination, the remaining potential source areas which were identified by the EPIC studies are unlikely to be contributing to groundwater contamination within the study area.

The highest concentrations of TCE and related compounds within the plume are observed in the area north of River Road. Monitoring wells MW8(D), MW5(D), MW15(S), MW15(D), CR26(D), and LF-13-43 exhibited the highest concentrations of TCE (see Figure 4-2). Generally, the deep monitoring wells installed in the unconsolidated deposits in this area had higher TCE concentrations than the shallow wells.

The detection of TCE in monitoring wells MW15S and MW15D suggests the presence of another potential source of groundwater contamination. Hydrogeologic data presented in Section 3.4.3 suggests that this contamination is unrelated to the TCE plume that may be originating from the area north of U.S. Route 13.

Isocontours of the hydraulic head for both the shallow and deep flow system indicate groundwater flow is toward Hog Run Creek. The hydraulic head difference at several well clusters in this area indicate an upward flow component. Hence, groundwater contamination associated with the plume emanating from Potential Source Area No. 1 would primarily discharge to the East Branch of Hog Run Creek. However, on the south side of the East Branch of Hog Run Creek, local groundwater flow is toward the northwest, in the opposite direction of regional flow. The TCE contamination detected in monitoring wells MW15S and MW15D is therefore likely to be associated with another source. Historical data suggest this contamination may be the result of the presence of another plume originating east of Route 413 (BCM, 1988).

Low levels of two pesticides, 4,4-DDT and dieldrin, were detected in groundwater at two locations. Monitoring well samples MW5(S)-1 and MW5(S)-1A (duplicate) contained DDT at concentrations of 0.3 µg/l and 2.0 µg/l, respectively. Dieldrin was detected in monitoring well samples LF-15-26-1 and LF-15-37-1 at concentrations of 0.30 µg/l and 0.28 µg/l. The source of these compounds is unknown.

An analysis of the occurrence and distribution of the inorganic constituents does not suggest groundwater contamination with metals within the study area. However, the levels of lead and chromium detected in several of the monitoring wells and/or residential wells is of potential concern.

The concentrations of lead (57 to 260 µg/l) and chromium (176 to 2,000 µg/l) in unfiltered groundwater samples obtained from the newly installed REM III shallow monitoring wells exceeded National Interim Primary Drinking Water Standard Maximum Contaminant Levels (MCLs) of 50 µg/l. All filtered monitoring well samples and unfiltered deep monitoring well samples contained lead and chromium below the MCLs. All of the unfiltered samples with high lead and chromium concentrations exhibited high Total Suspended Solid (TSS) levels. Acidification of these samples for preservation purposes most likely accounts for the high concentrations of lead and chromium.

One residential well exhibited lead in excess of the MCL. The reported value was 104K µg/l. In this case, the "K" qualifier indicates that the reported value may be higher than the actual value. This well was resampled in May 1988 and lead was again detected at 181 µg/l. However, there is no apparent pattern of lead contamination in groundwater within the study area. The detection of lead in these samples may be attributed to the use of lead piping in the homes.

Eight of the ten residential well samples analyzed contained nitrate (130 to 230 mg/l) in excess of the MCL of 10 mg/l. These wells were subsequently resampled in May 1988. None of

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the wells exhibited nitrate above 10 mg/l for the second round of samples. The results obtained by the initial sampling could have been in error which was caused during sampling or in the laboratory. Sampling errors could include unpure preservatives (H_2SO_4). Analytical errors could include incorrect calculations by the analyst. Nitrate was not detected at levels of concern in any of the monitoring well samples obtained within the contaminant plume.

During purging of the newly installed REM III monitoring wells, a white, immiscible liquid was identified in monitoring wells MW1(S), MW1(D), MW2(D), MW3(D), MW4(D), MW7(S), MW8(S), MW8(D), MW10(D), MW11(D), MW12(D), and MW14(S). The liquid was odorless and sank to the bottom of the holding container. The source, or chemical content of this liquid, is unknown. If this liquid is observed during the Phase II field investigation, a sample will be obtained and submitted for laboratory analysis.

4.2 SURFACE WATER AND SEDIMENTS

4.2.1 Scope of Sampling and Analysis

Surface water and sediments were sampled during the Phase I RI to determine the quality of local surface waters within the study area. Surface water and sediment samples were obtained from Hog Run Creek (including its East and West Branches), a pond located near the East Branch of Hog Run Creek behind the VFW Post, Neshaminy Creek, and the Delaware River upstream of the confluence of Neshaminy Creek. The sampling locations are shown on Figure 4-3.

A total of 13 surface water and 13 sediment samples were collected during dry weather conditions. The samples represent grab samples taken from the first few inches of sediment and from the water surface. All surface-water samples were analyzed for TCL organics, TAL inorganics, and cyanide. Sediment samples were analyzed for TCL volatile organics, TCL B/N/A extractable organics, TAL inorganics, and cyanide. The results are provided in Appendix J.

4.2.2 Nature and Extent of Contamination

Table 4-4 summarizes the surface water contamination identified within the study area. As indicated by this table, surface waters are not appreciably contaminated with organic or inorganic constituents. Volatile organic compounds are the principal contaminants identified in the samples. Volatile organic compounds detected include 1,1,1-trichloroethane (concentration range of 1.7 to 2 $\mu g/l$) and trichloroethene (concentration range of 2.3 to 6.1 $\mu g/l$).

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Figure 4-3
(see back pocket)

AR300396

TABLE 4-4
ORGANIC AND INORGANIC CONSTITUENTS
DETECTED IN SURFACE WATER
CROYDON TCE SITE

Compound	Maximum Detected Concentration(1)	Location (Maximum Concentration)
1,1,1-Trichloroethane	2.3	SW15
Trichloroethane	6.1	SW16
Aluminum	2,650L	SW9
Barium	[89]	SW11
Calcium	42,800-	SW11
Iron	3,460	SW9
Lead	16	SW3
Magnesium	18,900	SW11
Manganese	1,500J	SW15
Nickel	[13]	SW13
Potassium	39,300	SW11
Sodium	54,800	SW11
Vanadium	[8]	SW9
Zinc	86	SW9
Cyanide	33	SW12

Notes:

(1) All results reported in µg/l.

L: Denotes reported value may be biased low. Actual value is expected to be higher.

J: Denotes reported value is estimated. Actual value may be higher or lower.

[] Brackets indicate that the value reported is below the method detection level.

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Figure 4-3 illustrates the occurrence and distribution of the organic and inorganic constituents identified in the surface water samples. As shown in Figure 4-3, volatile organic compounds were not detected in surface-water samples obtained from Neshaminy Creek or the Delaware River (Station No. SW9). The principal surface water bodies affected by contaminants within the study area include Hog Run Creek (including the East and West Branches) and the pond located behind the VFW Post. The highest concentrations of TCE (6.1 µg/l) were detected on the West Branch of Hog Run Creek (Location SW12) and from the pond behind the VFW Post (Location SW16).

An evaluation of the occurrence and distribution of the volatile organic contaminants suggests that there is no apparent pattern of contamination (i.e., decreasing concentration with increasing distance from a source area). The presence of the volatile organic contaminants in surface water is most likely attributed to the discharge of contaminated groundwater to these surface water bodies.

As indicated in Section 4.1, groundwater contaminants associated with the plume discharge to Hog Run Creek and its branches. Additionally, a groundwater divide exists on the south side of the East Branch of Hog Run Creek which results in localized flow in the opposite direction of the regional groundwater flow. Consequently, the possible TCE plume that may be originating from the area east of Route 413 and/or the TCE plume identified within the study area are considered the principal source(s) of these contaminants. The highest concentrations of TCE in surface water were detected in the vicinity of monitoring wells that exhibited the highest TCE concentrations. Groundwater discharge with subsequent dilution and volatilization is considered the primary source of these compounds.

Although regional groundwater flow is toward the south-southeast, the effect of groundwater discharge to the Delaware River was not determined. Because of field sampling limitations, surface-water samples from the Delaware River in the vicinity of Hog Run Creek, and samples from the unnamed stream located north of Potential Source Area No. 1 were not obtained during the Phase I RI. Samples will be collected from these surface water bodies during the Phase II field investigation.

With respect to the inorganic constituents, none of the contaminants identified or the levels detected suggest widespread inorganic contamination within the study area. The types of compounds and concentrations identified appear to reflect natural background levels. With the exception of slightly elevated concentrations of zinc, the results of samples obtained within the study area are comparable with the concentrations detected at Sampling Location SW1, which is located outside of the study area.

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4.2.2.2 Sediment

Table 4-5 summarizes the extent of contamination detected in sediment samples collected from surface-water bodies within the study area. TCL organic contamination detected in the sediment samples includes volatile organics (toluene, trans-1,2-dichloroethene, and methylene chloride), polycyclic aromatic hydrocarbons (PAHs), and bis(2-ethylhexyl)phthalate.

Figure 4-3 illustrates the occurrence and distribution of the contaminants identified in the samples. As indicated in Figure 4-3, contamination within the study area is limited. Relatively low levels of toluene (maximum concentration 6 µg/kg) and trans-1,2-dichloroethene (maximum concentration 17 µg/kg) were detected in samples obtained from the pond behind the VFW Post and the Main Branch of Hog Run Creek. Both of these compounds were detected at relatively low concentrations.

Of the B/N/A extractable compounds, bis(2-ethylhexyl)phthalate was detected in the background sediment sample (Location SD1) obtained from Neshaminy Creek at a concentration of 870 µg/kg. PAHs (i.e., acenaphthylene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene) were detected in 8 of the 13 samples analyzed. As indicated in Figure 4-3, these compounds were found in samples obtained from the West Branch and Main Branch of Hog Run Creek and all sediment samples obtained from Neshaminy Creek.

The presence of PAHs does not necessarily suggest a widespread contamination in surface-water bodies within the study area. Although a source of contamination has not been characterized, the presence of these compounds may not be associated with a contaminant source. PAHs are common environmental pollutants and are formed during the combustion processes. These compounds readily adsorb to soil or sediment organic matter and will migrate as entrained soil particles. Runoff from adjacent roadways or the presence of motor boats are possible sources of the low-levels of PAHs detected throughout the study area. Neshaminy Creek contains numerous boat docks.

An analysis of the occurrence and distribution of inorganic constituents suggests inorganics are not considered a problem within the study area. The levels observed in samples obtained within the study area are generally comparable to the concentrations detected in the background sample (Location SD1 and SD2). Table 4-6 compares the concentrations detected in samples obtained within the study area to the concentrations detected in the site background samples. Slightly elevated levels of arsenic, copper, lead, manganese, zinc, and cyanide were detected in the study area. However, there is no apparent pattern of contamination. For example: lead may be present due to runoff from adjacent roadways. These constituents are not considered to be attributed to site-associated contamination.

ARJ00399

TABLE 4-5

ORGANIC AND INORGANIC CONSTITUENTS
DETECTED IN SEDIMENTS
CROYDON TCE SITE

Compound	Maximum Detected Concentration(1)(2)	Location (Maximum Concentration)
Toluene	6J	SD15
trans-1,2-dichloroethene	17J	SD15
Methylene chloride	16	SD11
bis(2-ethylhexyl)phthalate	870	SD1
Acenaphthylene	320J	SD3
Anthracene	1,100	SD3
Benzo(a)anthracene	1,700	SD3
Benzo(b)fluoranthene	3,000	SD3
Benzo(g,h,i)perylene	1,300	SD3
Benzo(a)pyrene	2,200	SD3
Chrysene	1,800	SD3
Fluoranthene	3,800	SD3
Indeno(1,2,3-cd)pyrene	1,500	SD3
Phenanthrene	2,500	SD3
Pyrene	3,500	SD3
Aluminum	13,800	SD4
Arsenic	28	SD11
Barium	206	SD13
Cadmium	6.9	SD11
Calcium	4,690	SD16
Chromium	37	SD11
Cobalt	[20]	SD13
Copper	140	SD16
Iron	59,000L	SD11

AR300400

TABLE 4-5
ORGANIC AND INORGANIC CONSTITUENTS
DETECTED IN SEDIMENTS
CROYDON TCE SITE
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Compound	Maximum Detected Concentration(1)(2)	Location (Maximum Concentration)
Lead	467K	SD16
Magnesium	2,810	SD4
Manganese	1,910L	SD13
Mercury	0.31	SD1
Nickel	[27] -	SD16
Potassium	2,400	SD12
Sodium	[1,490]	SD11
Vanadium	28	SD4
Zinc	757K	SD13
Cyanide	5.2	SD16

Notes:

- (1) Organic values are reported in µg/kg
- (2) Inorganic values are reported in mg/kg
- L: Denotes reported value may be biased low. Actual value is expected to be higher.
- K: Denotes reported value may be biased high. Actual value is expected to be lower.
- J: Denotes reported value is estimated. Actual value may be higher or lower.
- [] Brackets denote that reported value is below the method detection level.

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TABLE 4-6

COMPARISON OF INORGANIC CONCENTRATION
RANGES IN SEDIMENT TO SITE BACKGROUND CONCENTRATION RANGES
CROYDEN TCE SITE

Compound	Observed Concentration		Site Background*	
	Frequency	Concentration Range (mg/kg)	Frequency	Concentration Range (mg/kg)
Aluminum	12/12	3,700-13,800	2/2	3,140-9,370
Arsenic	11/12	2.1-28	2/2	2.5-9.1
Barium	12/12	23-206	2/2	22-105
Cadmium	12/12	1.4-6.9	1/2	2.3
Calcium	12/12	557-4,690	2/2	418-1,900
Chromium	12/12	9.4-37	2/2	6.6-19
Cobalt	10/12	4.1-20	1/2	7.7
Copper	11/12	8.2-140	2/2	7.2-35
Iron	12/12	9,360-59,000	2/2	8,710-15,400
Lead	12/12	8.4-467	2/2	13-31
Magnesium	12/12	1,220-2,810	2/2	980-2,220
Manganese	12/12	61-1,910	2/2	88-372
Mercury	0/12	-	1/2	0.31
Nickel	11/12	1-27	1/2	9.4
Potassium	11/12	216-2,400	2/2	391-418
Sodium	11/12	364-1,490	2/2	280-597
Vanadium	11/12	6.4-28	2/2	8.8-21
Zinc	12/12	91-757	2/2	19-86
Cyanide	1/12	5.2	0/2	ND

* Considers samples SD1 and SD2.

AR300402

4.3 SURFACE SOIL

4.3.1 Scope of Sampling and Analysis

As discussed in Section 2.2.4, it has been suggested that fill material from the Rohm & Haas landfill was placed in several areas in Croydon. These areas included the athletic fields near the Mary Devine Elementary School, the property of a private resident near River Road, and an area north of River Road across from Rohm & Haas Manufacturing Area B. To determine the presence or absence of contaminants in soils, eight surface soil samples were collected from these three locations. The sampling locations are shown in Figure 4-3. All of the samples were analyzed for TCL organics, TAL inorganics, and cyanide. The analytical results are provided in Appendix J.

4.3.2 Nature and Extent of Contamination

Table 4-7 summarizes the nature and extent of contamination detected in the soil samples. Contaminant occurrence and distribution is illustrated in Figure 4-3.

Organic compounds detected in surface soils include polycyclic aromatic hydrocarbons (PAHs), 4,4'-DDD, 4,4'-DDE, and polychlorinated biphenyls (PCBs) (Aroclor-1016 and Aroclor-1242). The soil results have been validated and the presence of these contaminants in the soil have been confirmed.

PCBs (Aroclor-1016 or Aroclor-1242) were detected at every sampling location at a concentration range of 163 to 590 µg/kg. The source of PCB contamination is unknown. Based on the available data, it cannot be determined whether these compounds are associated with the landfill, represent background levels, or are attributed to another unknown potential source.

PAHs were detected in six of the soil samples analyzed at all three sampling locations. The highest concentrations of individual PAHs were detected in samples collected from the local resident's yard. PAHs are common environmental pollutants resulting from combustion processes. Their detection in soils could represent expected background conditions or could potentially be attributed to a contaminant source. The former is more likely based on the levels detected.

Additionally, two pesticides (4,4'-DDD and 4,4'-DDE) were detected in soil sample SO-4 obtained from the athletic fields. 4,4'-DDD and 4,4'-DDE are metabolites of DDT, a pesticide which has been banned from use since the 1970s. DDT and its metabolites are persistent in the environment. Their detection may be attributed to historical pesticide use in this area. The Bucks County Mosquito Control Commission facility was formerly located between River Road and Hog Run Creek (BCM, 1988).

AR300403

TABLE 4-7

**ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN SURFACE SOIL SAMPLES
CROYDON TCE SITE**

Compound	Maximum Detected Concentration(1)(2)	Location (Maximum Concentration)
Acenaphthylene	2,800	SO4
Benzo(a)anthracene	2,700	SO4
Benzo(b)fluoranthene	12,000	SO4
Benzo(k)fluoranthene	610J	SO3
Benzo(a)pyrene	5,200	SO4
Chrysene	4,100	SO4
Dibenzo(a,h)anthracene	1,400	SO2
Fluoranthene	5,100	SO4
Indeno(1,2,3-cd)pyrene	4,100	SO4
Phenanthrene	1,200J	SO4
Pyrene	5,100	SO4
4,4'-DDD	110	SO4
4,4'-DDE	110	SO4
Aroclor-1016	590	SO4
Aroclor-1242	300	SO5
Aluminum	10,200L	SO7
Arsenic	14	SO7
Barium	194	SO2
Cadmium	2.7	SO1 SO2
Calcium	7,380	SO4
Chromium	34	SO4
Cobalt	[6.6]	SO1
Copper	116	SO2
Iron	22,200L	SO4

AR300404

TABLE 4-7
ORGANIC AND INORGANIC CONSTITUENTS DETECTED
IN SURFACE SOILS
CROYDON TCE SITE
PAGE TWO

Compound	Maximum Detected Concentration(1)(2)	Location (Maximum Concentration)
Lead	410K	S02
Magnesium	3,450	S07
Manganese	815L	S07
Mercury	0.28	S06
Nickel	[32]	S04
Potassium	3,290	S01
Sodium	[1,660]	S04
Vanadium	69	S04
Zinc	416K	S02

Notes:

- (1) Organic values are reported in µg/kg
- (2) Inorganic values are reported in mg/kg
- L: Denotes reported value may be biased low. Actual value is expected to be higher.
- K: Denotes reported value may be biased high. Actual value is expected to be lower.
- J: Denotes reported value is estimated. Actual value may be higher or lower.
- [] Brackets denote that reported value is below the method detection level.

AR300405

Various inorganic constituents were detected in the soil samples. Table 4-8 compares the observed concentrations to literature background values. Generally, the concentrations observed in all three sampling locations are within the range of expected background concentrations.

4.4 SUMMARY

A summary of the nature and extent of contamination identified in groundwater, surface water, sediments, and soils within the Croydon TCE Site study area is provided below.

- A plume of contaminated groundwater was identified in the southeastern portion of the study area. The plume appears to originate from the area north of U.S. Route 13. This plume extends south-southeast, in the direction of regional groundwater flow. Trichloroethene and related compounds are the predominant contaminants.
- The occurrence and distribution of groundwater contamination suggests the possible presence of a second TCE plume originating from an area east of Route 413. Localized groundwater flow is toward the northwest, opposite of the regional flow system in this area.
- Lead was detected above health-based standards in one out of 40 residential well samples. This compound appears to be unrelated to groundwater contamination that is associated with the site.
- Surface waters and sediments in Hog Run Creek and the pond behind the VFW Post contain relatively low levels of volatile organic compounds. Groundwater discharge to these surface waters is considered the source of these compounds.
- Sediments within the study area contain polycyclic aromatic hydrocarbons (PAHs) and slightly elevated levels of several inorganic constituents. Based on the available data, these constituents may be unrelated to contamination associated with the site.
- Surface soil samples were obtained from three areas in the site study area. Fill material from the Rohm & Haas landfill was allegedly placed in these areas. The samples contained PCBs, PAHs, and/or pesticides. Based on the available data, it is unknown whether these compounds are associated with the Rohm & Haas landfill, represent background levels, or are attributed to another potential contaminant source.

AR300406

TABLE 4-8

COMPARISON OF INORGANIC CONCENTRATION
IN SOIL TO LITERATURE BACKGROUND VALUES
CROYDEN TCE SITE

Compound	Observed Concentration		Background*
	Frequency (includes duplicate)	Concentration Range (mg/kg)	Concentration Range (mg/kg)
Aluminum	9/9	4,560-10,200	20,000-70,000
Arsenic	9/9	3.3-12	6.5-100
Barium	9/9	38-194	200-300
Cadmium	8/9	1-2.7	.01-7(a)
Calcium	9/9	404-7,380	130-5,200
Chromium	9/9	8.6-34	30-70
Cobalt	6/9	3.2-6.6	15-70
Copper	9/9	14-116	50-700
Iron	9/9	6,880-22,200	3,000-100,000
Lead	9/9	24-410	50-700
Magnesium	9/9	519-1460	2,000-7,000
Manganese	9/9	30-815	200-7,000
Mercury	2/9	.21-.28	.051-.2
Nickel	9/9	3.8-32	30-700
Potassium	3/9	272-3,290	16,000-65,000
Sodium	9/9	263-1,660	50-10,000
Vanadium	9/9	13-69	70-500
Zinc	9/9	49-416	190-3,500
Cyanide	1/9	1.5	NR

* All values from Shacklette and Boerngen (1984)
unless otherwise indicated.

a From McClanahan (1986).

NR None reported.

AR300407

5.0 PUBLIC HEALTH EVALUATION

5.1 INTRODUCTION

This public health evaluation (PHE) is designed to evaluate the magnitude and probability of actual or potential harm to public health, welfare, and the environment associated with the actual or threatened release of hazardous substances from the Croydon TCE Site. It is a site-specific risk assessment performed as part of the Phase I Remedial Investigation/Feasibility Study (RI/FS) performed under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) for hazardous waste sites. This public health evaluation is based on the Phase I analytical chemical data.

This baseline public health evaluation addresses the potential human health and environmental effects associated with the Croydon TCE Site under the no-action alternative. The no-action alternative assumes that no remedial (corrective) actions take place and that no restrictions are placed on future use of the groundwater at the site. Evaluation of the no-action alternative is required under Section 300.68(f)(v) of the National Contingency Plan (NCP) (EPA 1985b). This evaluation is consistent with guidelines from the Office of Emergency and Remedial Response as summarized in the Superfund Public Health Evaluation Manual (EPA 1986a) and Federal guidelines for risk assessment (EPA 1986b,c,d).

It should be noted that this PHE has been conducted using generally conservative assumptions according to the general guidelines outlined by EPA. The purpose of using conservative assumptions is to explore the potential for adverse health effects using conditions that tend to overestimate risk so that the final estimates will usually be near or higher than the upper end of the range of actual exposures and risks. As a result, this risk assessment should not be construed as presenting an absolute estimate of risk to human or environmental populations. Rather, it is a conservative analysis intended to indicate the potential for adverse effects to occur.

The assessment is organized as follows:

- Section 5.2 Identification of Site-related Chemicals. Chemicals detected in environmental media sampled during the RI (groundwater, soil, surface water, and sediment) are identified, and their distribution evaluated, to identify chemicals that are considered to be related to past activities at the site, and which will be evaluated in the risk assessment.
- Section 5.3 Environmental Fate and Transport. The factors that influence the migration potential of the chemicals of potential concern. The site environmental factors are discussed followed by a description of the

waste characteristics. Next, the physical and chemical properties of the chemicals of potential concern are presented. These are then combined to describe potential migration pathways of the chemicals of potential concern.

- Section 5.4 Exposure Assessment. Potential pathways by which populations may be exposed under current or potential future land use conditions are discussed. In addition, the concentrations of chemicals in environmental media at potential exposure points are identified. Concentration estimates are derived using available concentration data, and/or chemical-specific physical and chemical properties and models to describe the movement of chemicals in and between media.
- Section 5.5 Hazard Identification. Descriptions of the available information of the human health effects and environmental toxicity of the chemicals of potential concern are presented.
- Section 5.6 Human Risk Characterization. As one measure of risk, concentrations of site-related chemicals at exposure points are compared with applicable or relevant and appropriate requirements (ARARs). Since ARARs are not available for all chemicals in all media, quantitative risk estimates are also developed, where necessary, by combining the estimated intakes of potentially exposed populations (derived using conservative assumptions regarding exposure duration, route of exposure, frequency, and absorption of chemicals) with health effects criteria.
- Section 5.7 Environmental Assessment. In this section, the risk to environmental receptors that may come in contact with site-related chemicals will be evaluated. Potential receptors will be identified, relevant toxicity data will be summarized, and exposure will be assessed. These components will then be combined to evaluate the potential impacts of the site on biota.
- Section 5.8 Uncertainties. The uncertainties and limitations of this risk assessment are discussed.
- Section 5.9 Summary and Conclusions. The main features and conclusions of the risk assessment are summarized.

5.2 CHEMICALS OF POTENTIAL CONCERN

During the Phase I remedial investigation (RI), the soil, groundwater, surface water, and sediments at the Croydon site were sampled and found to be contaminated by a number of organic and inorganic compounds. To focus this public health evaluation, the chemicals associated with the greatest potential risks were selected for further evaluation at this site.

The selection of chemicals of potential concern was based on validated analytical data collected during the Phase I RI and the methodology presented in the Superfund Public Health Evaluation (PHE) manual (EPA 1986a). The selection process was performed on an environmental medium-specific basis to ensure that the threat to public health, welfare, and the environment would be evaluated with respect to compounds associated with the site. The criteria that were considered in selecting chemicals of potential concern include the presence of the chemical in background samples and in blanks, the extent and magnitude of chemical contamination, chemical and physical properties affecting fate and transport of the chemical in the environment, and chemical toxicity.

All chemicals detected in each medium sampled were evaluated in the selection process. This included both positively identified target compound list chemicals as well as tentatively identified chemicals. Chemicals of potential concern initially were screened based on a comparison to blanks and to background concentrations. Following this initial screening process, chemicals were considered for further evaluation based on their frequency of detection and toxicity.

Chemicals detected in samples at similar concentrations to those detected in laboratory, field, or trip blanks associated with the sample will not be selected for detailed evaluation. This includes chemicals (i.e. acetone) that may have been introduced during field or laboratory activities. Chemicals detected in samples at significantly higher levels than in blanks will be considered in the selection process after careful review of the site-relatedness of the reported chemical concentrations.

Concentrations of inorganic chemicals can be compared to background concentrations to determine if they may be present at naturally occurring concentrations, or if they have been elevated due to site activities. Appropriate background samples are located in areas where site-related chemicals are not expected to occur, that is off-site and sufficiently upgradient or distant to ensure that site-related contamination will not be present but in similar terrain. Since local background concentration data were not available for soils, regional background concentrations, obtained from the literature, were used as a basis for comparison. Because many of the organic chemicals of concern at the site are not found commonly in nature, a comparison of soil data to background will not be grounds for elimination from further consideration.

Inorganic compounds can be present in groundwater from natural sources. Local, upgradient residential and monitoring data were available and used to screen out inorganic constituents that were present due to natural sources. It is known that in some parts of the country naturally occurring levels are above drinking water standards. If this occurred, it was noted in the selection process.

AR300410

The chemicals remaining after the above initial screening were evaluated to determine if any additional chemicals could be removed because of infrequent detections. If the chemical was detected in approximately 5 percent or less of the samples in only one or possibly two environmental media, it was considered for removal based on frequency. However, before removal from consideration it was further evaluated to ensure that its limited frequency was not caused by its presence at potential hot spots or that it was not present at concentrations of potential concern based on its toxicity.

Chemicals for which U.S. EPA has not established human health toxicity criteria and for which available toxicity data indicate low toxicity were also considered for elimination from further consideration in the public health evaluation. Those chemicals for which U.S. EPA has not established human health toxicity criteria but which may not have low toxicity will be addressed in the discussion of uncertainty. These chemicals were, however, eliminated from quantitative evaluation in this assessment. The environmental effects of detected chemicals were also considered before they were eliminated from evaluation in the ecological risk assessment.

Several of the inorganic chemicals detected in the samples are considered to be essential nutrients for humans. Calcium, magnesium, and potassium are essential nutrients in the human diet (recommended daily allowances for adults are 800, 300-500, and 1,875-5,600 mg/day, respectively) and, in general, more attention has been given to problems of deficiency rather than toxicity. These minerals are typically obtained through food and drinking water (and sometimes mineral supplements), and the body generally has adequate physiological mechanisms to maintain a proper equilibrium over a wide range of intake levels. For this reason, these three elements are not selected as chemicals of potential concern.

Cobalt, copper, iron, manganese, selenium and zinc are essential metals with potential for toxicity. Each of these metals has three levels of biologic activity, trace levels required for optimum growth, storage levels, and toxic levels. For these metals, environmental accumulations are generally less important routes of excess exposure than accidents or occupational exposures (Klaassen 1986). Therefore, in the selection process, these chemicals are chosen as chemicals of potential concern only if concentrations are greatly elevated (i.e., at least 10 times) above background concentrations.

The analytical chemistry data are summarized using the representative concentration and the maximum detected concentration. The representative concentration of each chemical at the Croydon TCE Site is considered to be the geometric mean of the positive detections and in samples with non-detects, one-half the U.S. EPA 601/602 method detection limit for volatile organics, the U.S. EPA contract laboratory program (CLP) detection limit or, when available, the sample

detection limit. In the cases where the detection limit for a specific chemical is unusually high, use of half of this high detection limit would bias the mean, particularly when several samples have high detection limits. Hence, samples in which half of the detection limit exceeds the largest measured concentration of the chemical in that medium will not be used in calculating the mean. The geometric mean was used rather than the arithmetic mean because environmental data are generally log-normally distributed (Dean 1981). If a duplicate sample was collected and analyzed, reported concentrations are first averaged and the average of the two samples is used in calculating geometric means.

To summarize, the following criteria for identifying chemicals of potential concern were used:

- Frequency of detection. Chemicals that are detected only once in only one of the media sampled (e.g., soil, groundwater, surface water, or sediment) are eliminated from further consideration. In addition, chemicals which are detected in approximately 5 percent, or fewer, of the samples in only one or possibly two environmental media were also eliminated from further consideration.
- Comparison of naturally occurring inorganic chemicals with background concentrations. Chemicals are considered to be elevated above background if maximum levels detected in site samples are greater than the maximum background level.
- Essential nutrients. Calcium, magnesium, and potassium are essential nutrients in the human diet and, in general, more attention has been given to problems of deficiency rather than toxicity. These minerals are typically obtained through food and drinking water (and sometimes mineral supplements), and the body generally has adequate physiological mechanisms to maintain a proper equilibrium over a wide range of intake levels. For this reason, these three elements will not be selected as chemicals of potential concern.
- Cobalt, copper, iron, manganese, selenium, and zinc are essential metals with potential for toxicity. Each of these metals has three levels of biologic activity, trace levels required for optimum growth, storage levels, and toxic levels. For these metals, environmental accumulations are generally less important routes of excess exposure than accidents or occupational exposures (Klaassen 1986). Thus, these chemicals will be selected as chemicals of potential concern only if concentrations are greatly elevated (i.e., at least 10 times) above background concentrations.

AR300412

A specific discussion of the extent of contamination and the steps taken to select the chemicals of potential concern for each medium are presented in the following subsections.

5.2.1 Groundwater

Groundwater samples were taken from monitoring wells installed by NUS during the current RI, from Rohm & Haas wells installed during the site investigations conducted by BCM, and from residential wells in the study area. The monitoring and residential well data will be evaluated separately within this public health evaluation. This is because well installation information for the residential wells is not generally available. Also, some of the residential wells are currently being used and exposure to contaminants in these wells should be evaluated to ensure that there is no immediate threat to human health.

The monitoring wells were sampled at one or more depths within the same aquifer. Thus, monitoring well geometric means were calculated by aquifer using the complete monitoring well data set regardless of depth. The monitoring well data will be evaluated first in the selection of groundwater chemicals of potential concern.

Forty-six monitoring wells were sampled during the Phase I field investigation. Monitoring wells MW-13(S) and MW-13(D) were upgradient of the suspected source areas and were considered to be background wells. Table 5-1 summarizes the sampling data. The class of compounds detected most frequently in the groundwater were the chlorinated solvents. The most frequently detected chlorinated compounds were chloroform (23 of 43 samples), 1,1-dichloroethane (11 of 44 samples), 1,1-dichloroethene (12 of 44 samples), tetrachloroethene (20 of 44 samples), 1,1,1-trichloroethane (28 of 44 samples), and trichloroethene (24 of 44 samples). These six organics will be selected as chemicals of potential concern. None of the other chlorinated solvents detected in the monitoring wells less frequently were selected since their behavior will be similar to those selected. Toluene was the aromatic hydrocarbon detected most frequently (7 of 35 samples); however, it was not selected as a chemical of potential concern because of the very low concentrations detected. The maximum concentration was measured at an estimated value of 1.4 µg/l. Also selected as chemicals of potential concern were the potentially carcinogenic pesticides dieldrin and 4,4'-DDT. These two pesticides are not commonly found in groundwater and their presence may be indicative of a potential source of groundwater contamination.

AR300413

TABLE 5-1

**CHEMICALS DETECTED IN MONITORING WELL GROUNDWATER SAMPLES
CROYDON TCE SITE**

ORGANICS

Chemical	Frequency	Geometric Mean ($\mu\text{g/liter}$)	Maximum ($\mu\text{g/liter}$)
acetone	1/40	NA ^a	9.5 J ^b
benzene	1/44	NA	0.4 J
bis(2-ethylhexyl)phthalate	1/8	NA	4 J
bromodichloromethane	2/44	0.05	0.4 J
2-butanone	3/40	NRC	3 J
chloroform	23/43	0.15	8.9
dibromochloromethane	1/44	NA	0.3 J
1,1-dichloroethane	11/44	0.07	3 J
1,2-dichloroethane	4/44	0.02	5 J
1,1-dichloroethene	12/44	0.16	75
1,2-dichloroethene	5/44	0.065	4.6
4,4'-DDT	1/8	NA	0.77 J
dieldrin	2/8	0.08	0.3
tetrachloroethene	20/44	0.091	4.1 J
toluene	7/35	0.16	1.4 J
1,1,1-trichloroethane	28/44	0.46	160
1,1,2-trichloroethane	3/44	0.11	0.7 J
trichloroethene	24/44	1.1	420

TENTATIVELY IDENTIFIED COMPOUNDS

2,1,2-dichloroethane	2/44	NQ(d)	16 J
ethyl ether	2/44	NQ	0.5 J
1,1,2-trichloro-1,1,2-trifluoroethane	2/44	NQ	15 J
4-methyl-3-pentenoic acid	2/44	NQ	1.6 J
2-butene	2/44	NQ	2.7 J

AR300414

TABLE 5-1
CHEMICALS DETECTED IN MONITORING WELL GROUNDWATER SAMPLES
CROYDON TCE SITE
PAGE TWO

TENTATIVELY IDENTIFIED COMPOUNDS - CONTINUED

Chemical	Frequency*	Geometric Mean (µg/liter)	Maximum (µg/liter)
2-methyl-2-butene	1/44	NQ	0.5 J
1,1-dimethylcyclopropane	2/44	4.0	1.6 J
2-methyl-1-butene	1/44	NQ	0.4 J
cyclotetrasiloxane, octameth	1/44	NQ	10 J
cyclopentasiloxane, decameth	1/44	NQ	20 J
2-methyl-1-propene	1/44	NQ	1.3 J
2-methylpropane	1/44	NQ	2.8 J
1,1-dimethylcyclopropane	1/44	NQ	0.4 J
cyclopentane	1/44	NQ	1 J
2-methylpropane	1/44	NQ	8.2 J
cis-1,2-dimethylcyclopropane	1/44	NQ	1.3 J
3-methylenepentane	1/44	NQ	0.7 J
1-chloro-3-methylbutane	1/44	NQ	1.5 J
3-ethyl-2,2-dimethylpentane	1/44	NQ	1.2 J
2-methyl-1-pentene	1/44	NQ	1.2 J
4-methyl-1-pentene	1/44	NQ	1.2 J
3-methylpentane	1/44	NQ	1.5 J
1-ethyl-1-methylcyclopropane	1/44	NQ	0.3 J
2-hexene (Z)	1/44	NQ	1.2 J
3-methyl-1-pentene	1/44	NQ	0.1 J
methylcyclopentane	1/44	NQ	0.3 J
1,1-dimethylcyclohexane	1/44	NQ	0.7 J
3-methylhexane	1/44	NQ	0.6 J
heptane	1/44	NQ	0.4 J

AR300415

TABLE 5-1
CHEMICALS DETECTED IN MONITORING WELL GROUNDWATER SAMPLES
CROYDON TCE SITE
PAGE THREE

INORGANICS

Chemical	Frequency*	Geometric Mean (µg/liter)	Maximum (µg/liter)
aluminum	6/8	1,700	119,122
arsenic	2/8	4.0	7.8
barium	7/8	113	642
beryllium	3/8	2.3	5.9
calcium	8/8	8,800	28,200
chromium	2/8	11	191
cobalt	5/8	18	293
copper	3/8	25	122
iron	8/8	4,800	238,321
lead	6/6	16	66
magnesium	8/8	8,900	41,537
manganese	8/8	438	10,944
nickel	3/8	14	170
potassium	8/8	2,500	12,333
sodium	8/8	12,000	17,549
vanadium	3/7	17	243
zinc	5/8	40	553
cyanide	1/8	NA	12
nitrate	4/8	135	2,000
nitrite	7/8	289	4,180
ammonia	3/8	39	342
total suspended solids	6/8	70,000	3,322,000
total dissolved solids	8/8	108,000	161,000
alkalinity	8/8	9,000	24,800

AR300416

TABLE 5-1
 CHEMICALS DETECTED IN MONITORING WELL GROUNDWATER SAMPLES
 CROYDON TCE SITE
 PAGE FOUR

INORGANICS - CONTINUED

Chemical	Frequency*	Geometric Mean (ug/liter)	Maximum (ug/liter)
chloride	8/8	18,000	62,400
sulfate	7/8	31,000	76,400
total organic carbon	1/8	NA	1,000
biochemical oxygen demand	3/8	1,100	1,900

- (a) NA = Not Applicable. The geometric mean was not calculated due to only one positive detection.
 - (b) "J" designates estimated value.
 - (c) NR = Not Reported. Chemical was detected infrequently, and the use of one-half of the detection limit in calculating a mean result in a mean concentration that exceeds the maximum. Therefore, a mean is not used.
 - (d) NQ = Not Quantified. Because standard laboratory detection limits do not exist for tentatively identified compounds, a geometric mean of detected values and one-half detection limits may not be calculated.
- * Background wells (2) are not included.

AR300417

A number of tentatively identified compounds were detected in the groundwater. None of these compounds were selected as chemicals of potential concern because of their low frequency of detection. In some cases, there was insufficient toxicity information to adequately evaluate the risks associated with exposure.

To eliminate some of the naturally occurring inorganics from further evaluation, the maximum concentrations of the inorganics were compared with concentrations of inorganics found in local background wells. The wells MW-13(S), CR-RW5, CR-RW29, and CR-RW40 were designated as background wells since they were located upgradient of any of the potential source areas. Table 5-2 summarizes the background inorganic sampling results for wells MW-13(S) and CR-RW5 which were the only two designated background wells analyzed for inorganics. A comparison between the inorganic monitoring well data and background data reveals that levels of the inorganics found in both sets of wells are approximately the same. Therefore, no inorganic chemicals were selected as chemicals of concern.

It should be noted that the maximum lead and chromium levels found in the unfiltered groundwater samples from shallow wells exceeded the MCL and the proposed MCLG, respectively. These samples also exhibited high levels of total suspended solids. Filtered shallow monitoring wells and unfiltered deep monitoring well samples contained lead and chromium levels below the MCL and the proposed MCLG. It is not known whether or not the lead found in the samples were due to the presence of lead pipes in the homes; to a local, natural source; or to contamination. The lead data will be reevaluated after the Phase II data are available to determine how these concentrations relate to the site.

Forty residential wells, including those designated as background locations, were sampled during the Phase I RI. The sampling results are summarized in Table 5-3. The compounds selected as chemicals of potential concern for the monitoring wells were also found with high frequency in the residential wells, with the exception of the two pesticides, which were not detected. Thus, these compounds will be selected as chemicals of potential concern for these wells. 1,4-Dichlorobenzene was not selected as a chemical of potential concern. Although it is a potential carcinogen and was detected in 3 of 23 samples, the maximum detected was only 0.1 µg/liter, which is well below the MCL. All of the levels of inorganic compounds were within the range of background levels. Thus, none of these constituents were selected as chemicals of potential concern.

The final list of chemicals of potential concern for the groundwater are chloroform; 4,4'-DDT (for monitoring wells only); 1,1-dichloroethane; 1,1-dichloroethene; dieldrin (for monitoring wells only); tetrachloroethene; 1,1,1-trichloroethane; and trichloroethene.

AR300418

TABLE 5-2

CHEMICALS DETECTED IN BACKGROUND GROUNDWATER SAMPLES
CROYDON TCE SITEORGANICS^a

Chemical	Geometric Mean (ug/liter)	Maximum (ug/liter)
chloroform	NRC	0.006
1,1-dichloroethane	0.043	0.138
1,2-dichloroethane	0.029	0.412
1,1-dichloroethene	0.044	0.09
tetrachloroethene	0.081	0.33 ^b
trichloroethene	0.081	0.2 J

INORGANICS^a

aluminum	6,300	1,148,000
arsenic	7.2	31
barium	280	4,800
beryllium	4.3	45
cadmium	2.8	5.2
calcium	15,700	31,100
chromium	60	2,000
cobalt	37	744
copper	150	1,780
iron	45,200	1,499,00
lead	22	260
magnesium	16,000	167,000
manganese	630	10,100
mercury	0.22	1.1
nickel	39	1,690
potassium	8,860	51,500
sodium	9,100	17,200
vanadium	80	1,690

AR300419

TABLE 5-2
CHEMICALS DETECTED IN BACKGROUND GROUNDWATER SAMPLES
CROYDON TCE SITE
PAGE TWO

INORGANICS - CONTINUED

Chemical	Geometric Mean (µg/liter)	Maximum (µg/liter)
zinc	194	5,350
cyanide	5.8	39
nitrate	1,010	2,120
nitrite	116	143
ammonia	179	286
total suspended solids	323,000	33,010,000
total dissolved solids	54,000	1,300,000
alkalinity	6,200	43,200
chloride	7,100	20,200
sulfate	12,200	60,000
biological oxygen demand	6,800	122,000

- (a) Background samples include both monitoring well background samples and residential well background samples.
- (b) "J" designates estimated value.
- (c) NR - Not reported. Chemical was detected infrequently, and the use of one-half of the detection limit when calculating a mean results in a mean concentration that exceeds the maximum value detected. Therefore, a mean is not used.

AR300420

TABLE 5-3

**CHEMICALS DETECTED IN RESIDENTIAL WELL SAMPLES
CROYDON TCE SITE**

ORGANICS

Chemical	Frequency*	Geometric Mean (ug/liter)	Maximum (ug/liter)
benzene	1/33	NA(a)	0.62
bromodichloromethane	1/37	NA	0.019
butyl benzyl phthalate	2/33	4.7	8.2 J(b)
carbon tetrachloride	1/37	NA	0.24
chlorobenzene	1/37	NA	0.021
chloroform	6/17	0.08	1.2
1,2-dichlorobenzene	3/33	NR(c)	0.092
1,3-dichlorobenzene	2/33	0.19	0.213
1,4-dichlorobenzene	3/23	NR	0.114
1,1-dichloroethane	13/37	0.044	2.968
1,2-dichloroethane	3/35	0.021	3.308
1,1-dichloroethene	9/37	0.077	5.122 J
1,2-dichloroethene	6/37	0.038	0.057
ethylbenzene	1/37	NA	1.28
methylene chloride	1/5	NA	100 J
tetrachloroethene	24/35	0.069	4.302
1,1,1-trichloroethane	8/22	0.138	75.071
1,1,2-trichloroethane	5/37	NR	0.047
trichloroethene	10/20	0.74	97
trichlorofluoromethane	2/17	NR	0.023
vinyl chloride	1/37	NA	0.19 J

AR300421

TABLE 5-3
CHEMICALS DETECTED IN RESIDENTIAL WELL SAMPLES
CROYDON TCE SITE
PAGE TWO

INORGANICS - CONTINUED

Chemical	Frequency*	Geometric Mean (ug/liter)	Maximum (ug/liter)
aluminum	6/7	107	1,850
barium	6/7	48	106
calcium	7/7	8,420	14,676
copper	5/7	60	399
iron	4/7	330	9,100
lead	7/7	9	104
magnesium	7/7	6,200	11,000
manganese	7/7	45	184
mercury	3/7	0.13	0.2
nickel	3/7	8.7	16
potassium	7/7	1,450	3,880
sodium	7/7	10,100	26,300
vanadium	3/7	6.1	12
zinc	6/7	51	385
cyanide	1/7	NA	7.7
nitrate and nitrite	9/10	1,720	7,160
ammonia	3/10	32	300
total suspended solids	2/10	NA	413,000
total dissolved solids	10/10	160,000	320,000
alkalinity	5/5	44,000	71,000
chloride	10/10	20,000	49,000

AR300422

TABLE 5-3
CHEMICALS DETECTED IN RESIDENTIAL WELL SAMPLES
CROYDON TCE SITE
PAGE THREE

INORGANICS - CONTINUED

Chemical	Frequency*	Geometric Mean (µg/liter)	Maximum (µg/liter)
sulfate	10/10	37,000	86,000
biochemical oxygen demand	1/10	NA	9,900 J

- (a) NA = Not Applicable. The geometric mean was not calculated due to only one positive detection.
- (b) "J" designates estimated value.
- (c) NR = Not Reported. Chemical was detected infrequently, and the use of one-half of the detection limit in calculating a mean results in a mean concentration that exceeds the maximum. Therefore, a mean is not used.
- * Background wells are not included.

AR300423

5.2.2 Soil

Eight surface soil samples were taken during the Phase I round of sampling at three locations. Table 5-4 summarizes the sampling results and presents regional background results for the inorganics. 4,4'-DDD and 4,4'-DDE were detected in one sample and are not selected as chemicals of concern at this time. If, during the Phase II soil sampling, these two degradation products of 4,4'-DDT are found with a greater frequency, they may then be selected as chemicals of potential concern.

The polynuclear aromatic hydrocarbons (PAHs) detected at the site include acenaphthylene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene. Of these, all but acenaphthylene, fluoranthene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene are considered to be potentially carcinogenic and will be treated collectively. The noncarcinogenic PAHs were not selected due to the limited toxicity information available on these compounds. The potentially carcinogenic PAHs were detected in 6 of the 8 sampling locations and will be selected as chemicals of potential concern. However, it is unlikely that the PAHs are site related, but are present due to contributions from the urban environment (i.e., automobile emissions, factory emissions, etc.).

It should be noted that both PAHs and PCBs are ubiquitous components of the environment and the concentrations of these chemicals observed at the Croydon TCE Site may not be site-related. PAH soil concentrations of 6-300 mg/kg, well above those reported at the site, have been reported in urban areas of the United States (Blumer et al. 1977). PCB concentrations between 10 and 40 µg/kg have been reported for soils from 15 urban areas in the United States (EPA 1976).

The polychlorinated biphenyls (PCBs) Aroclor 1016 and Aroclor 1242 were detected in seven of eight the soil samples. They will be selected as chemicals of potential concern and will be treated collectively.

A comparison of the inorganic compounds measured in the surface soils with regional background concentrations reveals that all are present at or below background levels. As a result, no inorganic compounds will be selected as chemicals of potential concern.

Two tentatively identified compounds, benzofluoranthene and 1,6-dimethyl-4-(1-methylethyl)naphthelene, were detected in soils. These two compounds were not selected as chemicals of potential concern due to the uncertainty in their concentration as well as insufficient toxicity information to evaluate them. These chemicals are polynuclear aromatic hydrocarbons. If, at a

TABLE 5-4
CHEMICALS DETECTED IN SURFACE SOIL SAMPLES
CROYDON TCE SITE

ORGANICS

Chemical	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Background Values(a) (µg/kg)
acenaphthylene	2/8	260	2,800	-----
Carcinogenic PAHs				
benzo(a)anthracene	2/8	310	2,700	-----
benzo(b)fluoranthene	3/8	470	12,000	-----
benzo(k)fluoranthene	1/8	NA(c)	610 J(d)	-----
benzo(a)pyrene	2/8	350	5,200	-----
chrysene	4/8	340	4,100	-----
dibenz(a,h)anthracene	1/8	NA	1,400	-----
indeno(1,2,3-cd)pyrene	2/8	430	4,100	-----
TOTAL CARCINOGENIC PAHs	5/8	2,300	31,100	-----
4,4'-DDD	1/8	NA	110	-----
4,4'-DDE	1/8	NA	110.29	-----
fluoranthene	4/8	430	5,100	-----
phenanthrene	2/8	260	1,200 J	-----
Polychlorinated biphenyls				
Polychlor-1016	6/8	45	590	-----
Polychlor-1242	1/8	NA	290	-----
TOTAL PCBs	7/8	120	590	-----
pyrene	5/8	460	5,100	-----

TABLE 5-4
CHEMICALS DETECTED IN SURFACE SOIL SAMPLES
CROYDON TCE SITE
PAGE TWO

TENTATIVELY IDENTIFIED COMPOUNDS

Chemical	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Background Values (µg/kg)
benzofluoranthene	1/8	NQ(e)	4,000 J	-----
1,6-dimethyl-4- (1-methylethyl)- naphthalene	1/8	NQ	775 J	-----

INORGANICS

aluminum	8/8	7,240,000	10,200,000	20,000,000 - 70,000,000
arsenic	8/8	8,600	14,000	6,500 - 100,000
barium	8/8	65,000	194,000	200,000 - 300,000
cadmium	7/8	1,400	2,700	10 - 7,000(E)
calcium	8/8	1,730,000	7,380,000	130,000 - 5,200,000
chromium	8/8	14,000	34,000	30,000 - 70,000
cobalt	6/8	2,500	6,600	15,000 - 70,000
copper	8/8	31,500	116,000	50,000 - 700,000
iron	8/8	12,800,000	22,200,000	3,000,000 - <100,000,000
lead	8/8	72,000	410,000	50,000 - 700,000

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TABLE 5-4
CHEMICALS DETECTED IN SURFACE SOIL SAMPLES
CROYDON TCE SITE
PAGE THREE

INORGANICS - CONTINUED

Chemical	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Background Values (µg/kg)
magnesium	8/8	1,570,000	3,450,000	2,000,000 - 7,000,000
manganese	8/8	165,000	815,000	200,000 - 7,000,000
mercury	2/8	22	280	51 - 200
nickel	8/8	11,500	32,000	30,000 - 700,000
potassium	3/8	87,200	3,290,000	16,000,000 - 65,000,000
sodium	8/8	439,000	1,660,000	<50,000 - 10,000,000
vanadium	8/8	23,500	69,000	70,000 - 500,000
zinc	8/8	116,000	416,000	190,000 - 3,500,000
cyanide	1/8	NA	870	None Reported

- (a) Unless otherwise indicated, background values are from Schacklette and Boerngen (1984).
- (b) "B" designates that substance was also found in the blank, though the sample level was significantly higher to prove a positive effect.
- (c) NA - Not Applicable. The geometric mean was not calculated due to only one positive detection.
- (d) "J" designates estimated value.
- (e) NQ - Not Quantified. Because standard laboratory detection limits do not exist for tentatively identified compounds, a geometric mean of detected values and one-half detection limits may not be calculated.
- (f) From McClanahan (1986).

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later date, they were found to be potential carcinogens, then the evaluation of exposure to the potentially carcinogenic PAHs, would underestimate risk.

The soil chemicals of potential concern for the Phase I public health evaluation are the PCBs and carcinogenic PAHs.

5.2.3 Surface Water and Sediments

Surface water and sediment samples were taken in four surface water bodies within the Croydon TCE Site study area. The data are summarized in Table 5-5 and the sampling locations for each area indicated on the table are shown in Figure 4-3. Two samples were taken in the pond, five samples in both Hog Run Creek and Neshaminy Creek, and one in the Delaware River upstream of the confluence of Neshaminy Creek and the Delaware River. One sample taken in Neshaminy Creek upstream of the site study area, was collected as a background sample for the inorganic constituents.

1,1,1-trichloroethane and trichloroethene were detected in samples taken in the pond and in Hog Run Creek. Since they are suspected of being site related because they are present in the groundwater, they were selected as chemicals of potential concern.

The inorganic constituents detected in surface water were all found at levels approximately equal to background levels. Zinc was found above background in all the surface waters sampled, but was found at levels within the criteria range discussed earlier. Thus, zinc was not selected as a chemical of potential concern.

Acetone and toluene were detected in Hog Run Creek and in the pond sediments as shown in Table 5-6. The acetone results were all flagged with a "B" during data validation indicating that acetone is also present in associated blanks. Toluene was present in only one sample in each location and in the pond at an estimated value. As a result, neither acetone nor toluene was selected as a chemical of potential concern.

The carcinogenic PAHs were detected in Neshaminy Creek, Hog Run Creek, and the pond sediments and were not detected in the upgradient sediment samples. These compounds will be treated collectively and will be selected as chemicals of potential concern.

The inorganic constituents detected in the sediments were present at or below background with the exception of copper, lead, manganese, nickel, zinc, and cyanide. The metals were, however, present at levels within the regional soil background ranges. This presence at the site is not considered to be due to contamination, and their levels may be indicative of local geology rather than contamination. Thus, they will not be selected as chemicals of potential concern. Cyanide, which was

TABLE 5-5
CHEMICALS DETECTED IN SURFACE-WATER SAMPLES
CHOYDON TCE SITE(a)

ORGANICS

Chemical	Mechanist Creek			Delaware River (b)	Mag Run Creek			Pond			Background	
	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)		Concentration (ug/liter)	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Geometric Mean (ug/liter)
1,1,1-trichloroethane	0/3	ND(c)	ND(d)	0.015 U	2/5	0.10	1.8	2/2	2.2	2.3	0.015 U	ND
trichloroethane	0/3	ND	ND	0.06 U	3/5	0.76	6.1	2/2	3.8	6.1	0.06 U	ND
TENTATIVELY IDENTIFIED COMPOUNDS												
n-heptanone	0/3	ND	ND	ND	0/5	ND	ND	0/2	ND	ND	ND	132 J
1-butylcyclobutanol	3/3	58 J (e)	68 J	81 J	4/5	ND	60 J	0/2	ND	ND	ND	ND
3-nitro-1,2-benzenedicarboxylic acid	3/3	54 J	91 J	ND	4/5	ND	34 J	1/2	NA(f)	27 J	ND	ND
1,3-propeny-1-propene	0/3	ND	ND	ND	0/5	ND	ND	1/2	NA	57 J	ND	ND
2,3-dimethyl-pentanal	0/3	ND	ND	ND	0/5	ND	ND	1/2	NA	49 J	ND	ND
INORGANICS												
aluminum	3/3	1,100	1,480	2,650	5/5	248	444	2/2	200	260	2,220	2,250
barium	3/3	36	50	49	4/5	54	89	2/2	74	81	68	69
calcium	3/3	17,600	22,800	16,900	5/5	16,700	42,800	2/2	14,100	16,900	26,300	27,400
iron	3/3	1,500	1,990	3,460	5/5	930	3,020	2/2	1,200	1,600	1,845	1,850
lead	1/3	NA	16	9.2	0/5	ND	ND	1/2	NA	6.5	ND	ND
magnesium	3/3	6,880	8,520	6,290	5/5	11,300	18,900	2/2	10,600	10,500	9,650	10,100
manganese	3/3	121 J	219 J	159 J	5/5	290 J	610 J	2/2	1,200 J	1,500 J	92 J	94 J

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TABLE 5-5
CHEMICALS DETECTED IN SURFACE-WATER SAMPLES
CROYDON TCE SITE(a)
PAGE TWO

INORGANICS (CONTINUED)

Chemical	Mechaniny Creek			Delaware River(b)			Hog Run Creek			Pond			Background		
	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Concentration (ug/liter)	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Frequency	Geometric Mean (ug/liter)	Maximum (ug/liter)	Frequency	Geometric Mean (ug/liter)
nichel	0/3	NQ	ND	ND	3/5	8.4	13	2/2	9.5	10	ND	NQ	ND	ND	ND
potassium	3/3	2,760	3,980	2,300	5/5	7,700	39,300	2/2	5,760	6,570	4,930	4,500	4,930	4,930	4,930
sodium	3/3	12,600	19,500	10,400	5/5	27,100	54,800	2/2	19,000	20,900	25,500	25,500	28,400	28,400	28,400
vanadium	0/3	NQ	ND	8	0/5	NQ	ND	0/2	NQ	ND	ND	NQ	ND	ND	ND
zinc	3/3	48	68	86	5/5	47	64	2/2	65	70	22	22	27	27	27
cyanide	0/3	NQ	ND	ND	3/5	13	33	0/2	NQ	ND	NQ	NQ	ND	ND	ND

(a) Data summaries are provided for each water area.

(b) Only one sample was analyzed from the Delaware River.

(c) NQ = Not Quantified. Either because the compound was not detected, a mean is not calculated with only one positive detection, or standard laboratory detection limits do not exist for tentatively identified compounds, a geometric mean of detected values and one-half detection limits may not be calculated.

(d) ND = Not Detected

(e) "J" designates estimated value.

(f) NA = Not Applicable. Geometric mean not calculated with only one positive detection.

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TABLE 5-6
CHEMICALS DETECTED IN SEDIMENT SAMPLES
CROYDON TCE SITE

Chemical	Mashanley Creek			Delaware River(a)	Mog Run Creek			Pond			Background	
	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)		Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)	Maximum (µg/kg)
acenaphthylene	1/3	NA(d)	320 J(b)	MD(c)	0/5	MD	MD	0/2	MD	MD	MD	MD
anthracene	1/3	NA	1,100	MD	0/5	MD	MD	0/2	MD	MD	MD	MD
benzo(g,h,i)perylene	1/3	NA	1,300	MD	0/5	MD	MD	0/2	MD	MD	MD	MD
bis(2-ethylhexyl) phthalate	0/3	MD	MD	MD	0/5	MD	MD	0/2	MD	MD	380	870
carcinogenic PAHs												
benzo(a)anthracene	1/3	NA	1,700	MD	2/5	220	368 J	1/2	MA	780 J	MD	MD
benzo(b)fluoranthene	3/3	750	3,000	MD	1/5	NA	1,449	2/2	1,500	2,000	MD	MD
benzo(a)pyrene	1/3	NA	2,200	MD	2/5	220	363 J	1/2	MA	1,400	MD	MD
chrysene	1/3	NA	1,800	MD	2/5	230	408 J	1/2	MA	930 J	MD	MD
indene(1,2,3-cd)pyrene	1/3	NA	1,500	MD	0/5	MD	MD	1/2	MA	990	MD	MD
TOTAL CPAHs	3/3	2,270	10,200	MD	2/5	1,054	2,565	2/2	3,300	6,100	MD	MD
1,2-dichloroethane	0/3	MD	MD	MD	1/5	MA	13 J	2/2	7.1 J	17 J	MD	MD
fluoranthene	0/3	MD	MD	MD	2/5	360	1,396	2/2	1,200	1,200	MD	MD
methylene chloride	0/3	MD	MD	MD	1/5	NA	16	0/2	MD	MD	MD	MD
phenanthrene	1/3	NA	2,500	MD	2/5	220	390 J	0/2	MD	MD	MD	MD
pyrene	1/3	NA	3,500	MD	2/5	360	1,500	2/2	1,600	1,900	250	370 J
toluene	0/3	MD	MD	MD	1/5	MA	2.4 J	1/2	NA	6 J	MD	MD

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TABLE 5-6
CHEMICALS DETECTED IN SEDIMENT SAMPLES
CROYDON TCE SITE
PAGE TWO

TENTATIVELY IDENTIFIED COMPOUNDS

Chemical	Moshenny Creek			Delaware River(s)	Hog Run Creek			Pond			Background	
	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)		Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)	Maximum (µg/kg)
cholesterol	0/3	ND	ND	ND	0/5	ND	ND	0/2	ND	ND	ND	2,000 J
heptadecanoic acid, heptadecyl ester	0/3	ND	ND	ND	0/5	ND	ND	0/2	ND	ND	ND	400 J
stigmast-4-en-3-one	0/3	ND	ND	3,000 J	2/5	ND	5,000 J	0/2	ND	ND	ND	1,000 J
decanoic acid, 1,2,3-propametriyl ester	0/3	ND	ND	ND	0/5	ND	ND	0/2	ND	ND	ND	20,000 J
cineole	0/3	ND	ND	ND	2/5	ND	1,000 J	1/2	ND	1,000 J	ND	ND
alpha-pinene	1/3	ND(e)	600 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
1-methyl-4-(1-methyl-ethyl)-benzene	1/3	ND	600 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
1,2,3,4,6a,5,6,8a-octahydro-7-methyl-4-methylisophthalene	1/3	ND	400 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
1,2,3,4,4a,9,10,10a-octahydro-2,1,4a-trimethylphenanthrene	1/3	ND	3,000 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
1,1'-ethylidenebis-(4-ethyl)-benzene	1/3	ND	4,000 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
11H-benzofluorene	1/3	ND	800 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND

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TABLE 5-6
CHEMICALS DETECTED IN SEDIMENT SAMPLES
CHOYDON TCE SITE
PAGE THREE

TENTATIVELY IDENTIFIED COMPOUNDS (COMPOUNDS)

Chemical	Mechaniny Creek			Delaware River(s)	Wag Run Creek			Pond			Background	
	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)		Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)	Maximum (µg/kg)
1,2,3,4,6a,9,10,10A-octahydro-1-phenanthrene-carboxaldehyde	1/3	ND	3,000 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
benzofluoranthene	1/3	NA	1,000 J	ND	0/5	ND	ND	0/2	ND	ND	ND	ND
1,1-dimethylethyl-hydroperoxide	0/3	ND	ND	ND	2/5	ND	100 J	0/2	ND	ND	ND	ND
gamma-sitosterol	0/3	ND	ND	ND	1/5	NA	2,000 J	0/2	ND	ND	ND	ND
trichloroethane	0/3	ND	ND	ND	1/5	NA	90 J	0/2	ND	ND	ND	ND
2-heptanone	0/3	ND	ND	ND	1/5	NA	60 J	0/2	ND	ND	ND	ND
4-(3-turenyl)octahydro-1,7-dimethyl-2H-quinoline	0/3	ND	ND	ND	1/5	NA	1,000 J	0/2	ND	ND	ND	ND
1-ethenyl-1,2,3,4,4a,4b,5,6,7,8,8a,9-dodecamethyl-phenanthrene	0/3	ND	ND	ND	1/5	NA	2,000 J	0/2	ND	ND	ND	ND
1,6-dimethyl-4-(1-methyl-ethyl)-naphthalene	0/3	ND	ND	ND	0/5	ND	ND	1/2	NA	1,000 J	ND	ND

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TABLE 5-6
CHEMICALS DETECTED IN SEDIMENT SAMPLES
CROYDON TCE SITE
PAGE FOUR

INORGANICS

Chemical	Washemay Creek			Delaware River(a)			Mog Run Creek			Pond			Background	
	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Concentration (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)
aluminum	3/3	7,070,000	13,000,000	3,700,000	5/5	5,120,000	6,410,000	2/2	5,400,000	5,590,000	2/2	5,420,000	9,370,000	
arsenic	3/3	11,000	17,000	2,400	4/5	3,000	28,000	2/2	11,000	12,000	2/2	4,800	9,100	
barium	3/3	81,200	142,000	22,000	5/5	104,000	175,000	2/2	101,000	110,000	2/2	40,000	105,000	
cadmium	3/3	2,200	2,600	1,400	5/5	3,200	6,900	2/2	4,200	6,000	2/2	600	2,300	
calcium	3/3	1,960,000	2,530,000	557,000	5/5	1,820,000	4,000,000	2/2	2,700,000	4,690,000	2/2	991,000	1,900,000	
chromium	3/3	19,000	25,000	9,700	5/5	17,000	37,000	2/2	32,000	33,000	2/2	11,000	19,000	
cobalt	3/3	6,200	10,000	4,300	3/5	2,600	16,000	2/2	11,000	14,000	2/2	1,900	7,700	
copper	3/3	41,000	86,000	9,000	4/5	13,000	55,000	2/2	112,000	140,000	2/2	16,000	35,000	
iron	3/3	12,500,000	21,500,000	9,800,000	5/5	16,000,000	59,000,000	2/2	20,000,000	45,400,000	2/2	11,000,000	15,400,000	
lead	3/3	59,100	209,000	14,000	5/5	49,000	102,000	2/2	236,000	467,000	2/2	20,000	31,000	
magnesium	3/3	1,660,000	2,810,000	1,300,000	5/5	1,630,000	2,290,000	2/2	1,600,000	1,790,000	2/2	1,475,000	2,220,000	
manganese	3/3	252,000	605,000	133,000	5/5	200,000	1,287,000	2/2	203,000	1,310,000	2/2	181,000	372,000	
mercury	0/3	ND	ND	ND	0/5	ND	ND	0/2	ND	ND	0/2	ND	310	
nickel	3/3	12,000	17,000	9,500	4/5	6,100	26,000	2/2	10,000	27,000	2/2	2,400	9,400	
potassium	3/3	247,000	379,000	262,000	5/5	820,000	2,400,000	1/2	124,000	610,000	1/2	404,000	410,000	
sodium	3/3	394,000	456,000	50,100 W	5/5	696,000	1,490,000	1/2	191,000	730,000	1/2	409,000	597,000	

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TABLE S-6
CHEMICALS DETECTED IN SEDIMENT SAMPLES
CROYDON TCE SITE
PAGE FIVE

INORGANICS

Chemical	Moshaming Creek			Delaware River(a)		Mog Run Creek			Pond			Background	
	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Concentration (µg/kg)		Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Frequency	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)	Maximum (µg/kg)
vanadium	3/3	16,000	28,000	6,400		4/5	8,700	26,000	2/2	23,000	26,000	14,000	21,000
zinc	3/3	165,000	101,000	88,000		5/5	103,000	651,000	2/2	384,000	505,000	40,000	8,000
cyanide	0/3	ND	ND	ND		0/5	ND	ND	1/2	1,600	5,200	ND	ND

(a) Only one sample was analyzed from the Delaware River.

(b) -J- designates estimated value.

(c) ND = Not Detected

(d) NA = Not Applicable. The geometric mean was not calculated due to only one positive detection.

(e) NQ = Not Quantified. Because standard laboratory detection limits do not exist for tentatively identified compounds, a geometric mean of detected values and one-half detection limits may not be calculated.

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septic tanks, for example. If the soil is assumed to be the source, some of the contaminants have been adsorbed to the soil while others have been transported downward through the soil via rainwater infiltration. The presence of mixtures of chemicals may enhance the mobility of certain chemicals which would otherwise be relatively immobile. When contaminants are present in surface soils, they may be volatilized to the air, released to the air as fugitive dust if adsorbed to soil particles in an area that is unvegetated, or transported to surface water via surface water runoff.

5.3.3 Physical and Chemical Properties of the Chemicals of Potential Concern

The environmental fate and transport of contaminants is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they are migrating. Physical and chemical properties of the potential organic chemicals of concern are summarized in Table 5-8.

The water solubility of a substance is a critical property affecting environmental fate. Highly soluble chemicals can be rapidly leached from wastes and soils and are generally mobile in groundwater. Solubilities range from less than 1 mg/liter to totally miscible with most common organic chemicals falling between 1 mg/liter and 1,000,000 mg/liter (Lyman et al. 1982). The solubility of chemicals which are not readily soluble in water may become enhanced in the presence of organic solvents which themselves are more soluble in water (e.g., trichloroethene with toluene).

Volatilization of a compound will depend on its vapor pressure, water solubility, and diffusion coefficient. Highly water soluble compounds generally have lower volatilization rates from water unless they also have high vapor pressures. Vapor pressure, a relative measure of the volatility of chemicals in their pure states, ranges from about 0.001 to 760 mm Hg for liquids, with solids ranging down to less than 10^{-10} mm Hg. The Henry's law constant, which combines vapor pressure with solubility and molecular weight, is more appropriate for estimating releases from water to air. Compounds with Henry's law constants in the range of 10^{-3} atm-m³/mol and larger can be expected to readily volatilize from water; those with values ranging from 10^{-3} to 10^{-5} atm-m³/mol are associated with possibly significant, but not facile, volatilization, while compounds with values less than 10^{-5} atm-m³/mol will only volatilize from water (slowly) to a limited extent (Lyman et al. 1982). The diffusion coefficient (diffusivity) can be used as a means to predict the rate at which a compound moves through the environment. Molecular diffusion is determined by both molecular properties (e.g., size and weight) and by the presence of a concentration gradient which means that molecules of a chemical will migrate to areas deficient in molecules of that compound.

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TABLE 5-8

PHYSICAL-CHEMICAL PROPERTIES OF CHEMICALS OF POTENTIAL CONCERN
CROYDEN TCE SITE

Compound	Molecular Weight (g/mol)	Diffusivity (cm ² /sec)	Solubility in Water (mg/l)	Vapor Pressure (mm Hg)	Henry Law Constant (atm-m ³ /mol)	Koc	LOGKow
CHLORINATED ALIPHATICS							
chloroform	119.00	0.08868	8.20E+03	1.51E+02	3.80E-03	3.10E+01	1.97
1,1-dichloroethane	98.96	0.09590	5.50E+03	1.82E+02	5.70E-03	3.00E+01	1.79
1,1-dichloroethene	96.94	0.10077	2.25E+03	6.00E+02	1.54E-01	6.50E+01	2.13
tetrachloroethene	165.85	0.07404	1.50E+02	1.78E+01	2.30E-02	3.64E+02	2.60
1,1,1-trichloroethane	133.41	0.07965	1.50E+03	1.23E+02	2.80E-02	1.52E+02	2.50
trichloroethene	131.29	0.08116	1.10E+03	5.79E+01	8.90E-03	1.26E+02	2.38
PESTICIDES							
4,4'-DDD	320.00	0.04742	1.00E-01	1.89E-06	7.96E-06	7.70E+05	6.20
4,4'-DDE	318.00	0.05336	4.00E-02	6.50E-06	6.80E-05	4.40E+06	7.00
4,4'-DDT	354.49	0.04467	5.00E-03	5.50E-06	5.13E-04	2.43E+05	6.19
dieldrin	380.95	0.04875	1.95E-01	1.78E-07	4.58E-07	1.70E+03	3.50

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TABLE 5-8
PHYSICAL-CHEMICAL PROPERTIES OF CHEMICALS OF POTENTIAL CONCERN
CROYDEN TCE SITE
PAGE TWO

Compound	Molecular Weight (g/mol)	Diffusivity (cm ² /sec)	Solubility in Water (mg/l)	Vapor Pressure (mm Hg)	Henry Law Constant (atm-m ³ /mol)	KOC	LOGKow
POLYCHLORINATED DIPHENYLS							
aroclor-1016	257.90	0.05925	4.20E-01	4.00E-04	3.30E-04	1.80E+05	5.58
aroclor-1242	266.50	0.05829	2.30E-01	1.30E-03	1.98E-03	6.30E+03	4.11
POLYNUCLEAR AROMATIC COMPOUNDS							
benzo(a)anthracene	228.00	0.04654	5.70E-03	2.20E-08	1.16E-06	1.38E+06	5.61
benzo(b)fluoranthene	252.00	0.04392	1.40E-02	5.00E-07	1.19E-05	5.50E+05	6.06
benzo(k)fluoranthene	252.00	0.04392	4.30E-03	5.10E-07	3.94E-05	5.50E+05	6.06
benzo(a)pyrene	252.00	0.04653	3.80E-03	5.60E-09	1.55E-06	5.50E+06	6.06
chrysene	228.00	0.04531	1.80E-03	6.30E-09	1.05E-06	2.00E+05	5.61
dibenzo(a,h)anthracene	278.00	0.05707	1.40E-02	1.00E-10	2.61E-09	3.30E+06	5.61
indeno(1,2,3-cd)pyrene	276.00	0.05728	5.30E-04	1.00E-10	6.86E-08	1.60E+06	6.50

Sources: Callahan et al., 1979; Lyman et al., 1982; Mabey et al., 1982; Mackay and Shui, 1981; Shen, 1982; Verschueren, 1983.

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The octanol-water partition coefficient (K_{ow}) is often used to estimate the extent to which a chemical will partition from water into lipophilic parts of organisms, for example, animal fat. Chemicals with high K_{ow} values are likely to bioaccumulate in exposed organisms. Similarly the organic carbon partition coefficient (K_{oc}) reflects the propensity of a compound to sorb to the organic matter found in the soil. The normal range of K_{oc} values is from 1 to 10^7 , with higher values indicating greater sorption potential.

As indicated in Table 5-8, the organic chemicals of concern can be classified into categories according to their similarity in chemical structure and/or physicochemical properties (factors which would influence mobility in the environment). The organic chemical categories and the chemicals of concern within each category are listed below along with the inorganic chemical of concern:

- Chlorinated aliphatics: chloroform, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene.
- Pesticides: 4,4'-DDT and dieldrin.
- Polycyclic aromatic hydrocarbons: benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
- Polychlorinated biphenyls: Aroclor 1016 and Aroclor 1242.

5.3.4 Mechanisms of Migration

There are several mechanisms by which contaminants may migrate within the study area. The contaminated soils can act as a source of contamination to the other environmental media. Migration into the air can occur via volatilization or fugitive dust emissions; transport into the creeks and the Delaware River can occur via surface runoff and groundwater discharge; and migration into groundwater can occur by percolation of infiltrating rainwater with subsequent leaching and transport. One other process that will influence migration is the biotransformation of certain organic compounds. The potential for the organic chemicals of potential concern to be influenced by and migrated via these mechanisms is described in the following subsections.

5.3.4.1 Migration into Air

The mechanisms of organic volatilization are complex. Volatilization is the mass transfer of an organic compound from a specific medium (e.g., water) to the air. The ability for this transfer or migration to occur will depend on the other competing processes which would hinder this migration. 1000441

example, if a chemical is very soluble in water, it will be less likely to volatilize into the air. Environmental factors of importance in soil migration include temperature, soil porosity, amount of water present in the soil, soil organic carbon content, and depth of contamination (Jury et al. 1983).

Generally, compounds with high vapor pressures or high Henry's law constants are expected to volatilize readily. Of the chemicals of potential concern at the Croydon TCE Site, the halogenated aliphatics (chloroform, 1,1-dichloroethane, tetrachloroethene, 1,1-dichloroethene, 1,1,1-trichloroethane, and trichloroethene) have high vapor pressures and Henry's law constants greater than 1×10^{-3} atm-m³/mol which means they have a tendency to volatilize from soils and water.

However, while the other chemicals of potential concern such as 4,4'-DDT, dieldrin, polychlorinated hydrocarbons (PCBs), and the polycyclic aromatic hydrocarbons (PAHs) have substantially lower vapor pressures, they also have low water solubilities with the net result being that substantial volatilization can still occur (EPA 1976, 1986a).

Fugitive dust emissions could occur at the Croydon TCE Site in areas that are unpaved or unvegetated, such as the ballfields. Only PCBs and PAHs were found in the soils; the compounds have low water solubilities and high organic carbon partition coefficients (K_{oc}) and would be expected to remain in the surface soil and could be transmitted by fugitive dust. The potential for fugitive dust emission is primarily dependent on environmental factors such as percent silt, moisture content, vegetative cover, and wind speed.

5.3.4.2 Percolation into Groundwater

Compounds present in the soils at the Croydon TCE Site are PCBs and PAHs. These are classes of compounds which include chemicals with a range of solubilities. For PAHs and PCBs the solubilities generally increase with decreasing molecular weight, and the possibility of migration also increases with greater solubility. Therefore the lower molecular weight PAHs and PCBs might be leached into the groundwater, but the higher weight compounds are not very mobile and would not be expected to be leached into the groundwater by precipitation infiltrating into soils. However, the organic chemicals of concern with a high solubility and low K_{oc} s are particularly susceptible to this phenomenon. The halogenated aliphatics are relatively soluble with aqueous solubilities of 1.5×10^2 to 8.20×10^3 mg/L and are, therefore, expected to be more mobile than the other chemicals of concern. Most of these are to be found in the groundwater. The source of the contamination at the Croydon site is not currently known. It is possible that the halogenated aliphatics were originally dumped in soils and have leached via the above mentioned mechanisms to the groundwater.

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Once in the groundwater, the compounds with low water solubilities and high organic carbon absorption coefficients (K_{oc}) are transported in the direction of the groundwater flow but at a much slower rate than the groundwater. This is because compounds moving with the groundwater flow tend to partition or divide themselves between the mobile water or aqueous phase and the stationary soil particles that are in contact with groundwater. The overall effect of this sorption process is a retardation of the rate of a compound's transport. The halogenated aliphatic chemicals of potential concern have relatively high solubilities and low K_{oc} s that indicates that they are very mobile in groundwater at the Croydon site.

5.3.4.3 Migration in Surface Water

The Neshaminy and Hog Run Creeks and the Delaware River all flow through or adjacent to the study area. Groundwater discharges into the creeks and river under natural conditions, can result in the input of contaminants into these areas. Upon reaching the surface water, the more volatile chemicals of concern are likely to volatilize to the air while those chemicals which have low solubilities and/or K_{oc} s will tend to be deposited in the sediments. These sediment associated contaminants can then be slowly distributed downstream through normal flow of the surface water, or in slugs during storm-events. This distribution is demonstrated by the fact that the less soluble PAHs are found only in the sediments while 1,1,1-trichloroethane and trichloroethene, which are more soluble, are found only in the surface water.

5.3.4.4 Biodegradation and Biotransformation Processes

Biological and chemical processes that occur in the soil and sediments can be important in determining the ultimate fate of the chlorinated aliphatics found at the Croydon TCE Site. The extent and rates of these reactions, however, are difficult to predict because of a limited scientific data base. The state of knowledge in the field is summarized below and has been reported in recent reviews (SAIC 1985, Smith and Dragun 1984). Under anaerobic or oxygen depleted conditions, chlorinated aliphatic chemicals (e.g. TCE) have been found to undergo reductive dechlorination reactions, that is, reactions which remove chlorine from and add hydrogen to the chemical (Bouwer et al. 1981, Kobayoshi and Rittman 1982). One exception to this is the aerobic degradation of trichloroethene in the presence of methane (Wilson and Wilson 1984). The transformation is sequential with, for example, tetrachloroethene (an ethene molecule with four chlorines) yielding trichloroethene (an ethene molecule with three chlorines) producing 1,1-dichloroethene (an ethene molecule with two chlorines) and ultimately vinyl chloride (an ethene molecule with one chlorine) (Parsons et al. 1984, Cline and Viste 1984).

Chloroform has been found to degrade to methylene chloride in laboratory studies (Bouwer 1983). Wilson and coworkers

(1981, 1983) did not observe this degradation in field studies and attributed this to the high mobility of chloroform in the soils (i.e. it volatilizes or percolates to the groundwater).

PCBs are metabolized by microorganisms present in the environment. Metabolism of one PCB will sequentially yield PCBs of lower molecular weight and greater solubility. Thus metabolism of PCBs in the environment will increase the mobility of the compound. The nature and extent of degradation, as well as the type and number of products, appears to be highly dependent on soil conditions. Some investigators (Wilson et al. 1983, Schwarzenbach et al. 1983) found no transformation in soil, while others (Kleipfer et al. 1985, Parsons et al. 1984) found substantial transformation.

The PAHs sorbed onto soil can also be biodegraded. Factors which contribute to degree to which biodegradation occurs include biodegradability rates, production of intermediates, and the effects of mixtures. In general, PAHs with 2 or 3 rings (i.e., phenanthrene) are more readily degraded than PAHs with 4 or more rings (i.e., pyrene).

In most cases, an organic contaminant is not broken down completely to carbon dioxide and water by a bacterium, but is metabolized to an intermediate which is in turn further degraded. The metabolites isolated depend primarily on the time at which the reaction is stopped. In the course of the degradation of phenanthrene to low molecular weight carboxylic acids by soil Pseudomonads (bacteria), a total of 24 different metabolites have been either isolated or proposed as intermediates (Pucknat 1981). All of these intermediates are more water soluble than the parent compound and are therefore more mobile. Many of them are also more toxic.

5.4 EXPOSURE ASSESSMENT

An exposure pathway is complete if four elements are present: (1) a source and mechanism of chemical release to the environment, (2) an environmental transport medium (e.g., groundwater, surface water), (3) a point of potential contact with the contaminated medium (the exposure point), and (4) an exposure route at the contact point. The purpose of this section is to identify current and future human and environmental populations potentially exposed to site contaminants within the Croydon TCE Site study area and the pathways through which they would be potentially exposed.

To provide a framework for this information, current and plausible future land uses are identified. Populations potentially exposed to contaminants originating in the Croydon TCE Site are discussed together with potential exposure pathways and the likely extent of exposure. Finally, exposure estimates are developed for the exposures considered to be potentially significant and for which risk estimates will be made later in this assessment. Two scenarios are considered for each exposure

scenario. The average case will use the geometric mean concentration and average exposure and intake assumptions. The plausible maximum case will use the maximum concentration detected and upper bound exposure assumptions. Table 5-9 summarizes the potential exposure pathways which will be discussed in this section. As can be seen in the table, exposure can occur through all environmental media.

5.4.1 Site and Surrounding Area Under Current Use Conditions

The Croydon TCE Site is used primarily for residential purposes. There are, however, several light industries in the area as well. This section will discuss the exposure pathways shown in Table 5-9 which are complete under current-use conditions at the site.

5.4.1.1 Soil

As has been discussed previously, the soil sampled in three locations at the Croydon TCE Site is contaminated with PCBs and PAHs. Individuals and wildlife using the study area could potentially be exposed to these compounds. The three areas of soil contamination considered in this assessment are the ball fields near the Mary Devine School, a residence along River Road, and an area across from Manufacturing Area B. Only the ballfields and the residence are considered under the current use scenario. Exposure to contaminants in the soil of the industrial area are considered for future use.

Individuals using the ball fields can be exposed to soil contaminants via direct contact and incidental ingestion. It is assumed for this scenario that for the average case an individual would be outside for 30 days per year, for 5 years. For the plausible maximum case, it is assumed that the individual uses the ball fields 50 days a year for 20 years. The concentrations in soils that this individual may be exposed to are presented in Table 5-10.

Children reside within the study area and may go to school at the Mary Devine School adjacent to the ball fields. There is a fenced-in playground at the school and the children are unlikely to stray from it. After school and on the weekends during good weather, these children are likely to play outdoors. They will, however, probably play most of the time in their own backyards. Residential exposures of children, as well as adults, will be addressed under current use conditions by considering lifetime exposure to chemicals of potential concern detected in the soils of the residence on River Road. The concentrations of the chemicals of potential concern in this area are presented in Table 5-10. It is conservatively assumed that the concentrations of the chemicals of potential concern remain constant over time. A lifetime average exposure of 100 and 160 days per year over a 70-year lifetime are assumed for the average and plausible maximum case, respectively.

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TABLE 5-9

**POTENTIAL PATHWAYS OF EXPOSURE TO CONTAMINANTS
ORIGINATING AT THE CROYDON TCE SITE**

Exposure Medium	Potential Routes of Exposure	Potential Receptors	Potential for Significant Exposure
Soil	Dermal contact, incidental ingestion	Individuals using the ball fields	Soils are contaminated, but the extent of contamination is not well defined.
		Children, adults	In the future, the entire site area could be redeveloped for residential use.
	Ingestion of contaminated vegetation	Wildlife	Wildlife inhabit the area and have access to the site.
Groundwater	Ingestion, inhalation, dermal contact	Residences or industries using groundwater for drinking water and other purposes	Groundwater is currently used to a limited extent for drinking water and other household uses. The aquifer in the study area has been used for drinking water purposes and could be used in the future; thus, potential for exposure is high in the future. Individuals could choose to develop groundwater wells for private use.
Surface Water/Sediment	Uptake by wildlife	Aquatic life, wetland community	Surface water and sediment contaminated
	Dermal contact, incidental ingestion	Individuals in the area	Mechaminy Creek is used for recreational purposes. Hog Run Creek may be used by children. The pond is not known to be used for any purpose.
Air	Inhalation of volatile contaminants from soil and/or fugitive dust	Individuals in the area	Surface soils contain organic compounds of limited volatility. These compounds are known to adsorb strongly to soil. Probability of exposure decreases because most of the study area is developed, paved, or vegetated.

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TABLE 5-10

CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN
IN THE
CROYDON TCE SITE SOILS

Compound	Baseball Field		Residence	
	Geometric Mean (µg/kg)	Maximum (µg/kg)	Geometric Mean (µg/kg)	Maximum (µg/kg)
PAHs(a)	1,264	1,532	3,708	11,905
PCBs(b)	48.8	290	231	295

(a) Carcinogenic polynuclear aromatic hydrocarbons

(b) Polychlorinated biphenyls

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It is likely that a number of animals inhabit the Croydon TCE Site. This population could also be exposed to contaminants present in the soil. Exposure to environmental receptors will be discussed in detail in Section 5.7.

Another route of exposure via the soil pathway is that of individuals growing vegetables for consumption. Vegetables grown on contaminated soil could concentrate the chemicals of potential concern in the edible portion of the plant. The individual or animal ingesting the vegetables would then be exposed to these compounds. Information is not currently available which identifies the occurrence of gardening in the River Road residence where soil contamination has been detected, or if gardening does occur, what crops are grown and where they are grown in relation to identified contaminated areas. Once these data and additional soil data have been obtained, this pathway may be complete and may be quantified.

Finally, exposure to contaminants present in soils by inhalation of dust could occur. This exposure pathway is not quantified here because of the limited area of unvegetated or uncovered soil (i.e., most of the site is built on or vegetated). Additionally, dust generated by individuals playing softball is considered to be limited in duration and quantity of dust produced. Thus, this exposure pathway also will not be evaluated.

5.4.1.2 Groundwater

Under current land use conditions, the groundwater may be used for drinking water purposes since not all the homes and businesses are served by the city water supply. The groundwater chemicals of potential concern for residential wells will be evaluated under the current-use scenario. Table 5-11 summarizes the exposure point (i.e., residential well) concentrations for the ingestion of groundwater. The table presents the geometric mean and maximum values of the chemicals of potential concern in all residential wells sampled.

The groundwater concentrations of chemicals of potential concern in residential wells summarized in Table 5-11 were used to estimate the concentrations that people might be exposed to from using water containing these volatile organics. The literature (e.g., Sorrell et al. 1985) indicates that there are numerous potential sources from which volatiles can escape into indoor air during water use. For this assessment, showering, taking a bath, using a dishwasher, flushing toilets, washing clothes, housecleaning, and general use of water for cooking and other kitchen purposes were evaluated. Exposures potentially resulting from showering were evaluated using a mathematical model developed for this purpose (Foster and Chrostowski 1987). This model assumes that the shower water temperature is 45°C (113°F), that a person showers for 15 minutes and remains in the room for an additional 5 minutes, and that the person breaths 15 liters of air per minute and weighs 70 kg (154 lbs).

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TABLE 5-11

CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN
IN THE RESIDENTIAL WELLS
CROYDON TCE SITE

Compound	Concentration (µg/liter)	
	Geometric Mean	Maximum
chloroform	0.081	1.2
1,1-dichloroethane	0.044	3.0
1,1-dichloroethene	0.077	5.12
tetrachloroethene	0.069	4.30
1,1,1-trichloroethane	0.14	75.1
trichloroethene	0.74	97.0

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Additional assumptions concerning input parameters of the model are presented in Appendix K. The model has been validated by independently obtained laboratory data for an experimental shower, and yields air concentrations that are within 10 percent of the true values.

Detailed, validated models have yet to be developed for the other potential sources of volatiles. In order to evaluate their contributions to the overall indoor air loading, recourse was made to measurements made with radon gas by Prichard and Gesell (1981). These investigators measured the amount of radon liberated during use of domestic water for various activities including showering. Assuming that volatile organics behave similarly to radon, Prichard and Gesell's data were used to derive ratios which were then applied to the shower concentrations calculated via the model and thus estimate the amount of volatile organics associated with various activities (see Appendix K). This approach is discussed more completely in Section 5.6.3.2.

It was also necessary to estimate dermal exposure. Wester and co-workers (1987) measured the amounts of benzene which were transferred to human skin from dilute solution in water over a 30-minute period. In order to conservatively use this data, the amounts of benzene absorbed through the skin and the amounts found in various layers of the skin (epidermis, dermis, stratum corneum) were summed together. It was assumed that this was the amount of benzene which could be transferred into the skin during a bath. Since dermal absorption of organic chemicals from dilute solution is, to a first approximation, proportional to the lipophilicity of the chemicals (Foster and Chrostowski 1986), doses for the chemicals of potential concern were derived on the basis of the benzene dose and the ratio of the octanol-water partition coefficient of benzene to those of the chemicals of potential concern. This calculation assumed that a bath lasted 30 minutes and that 80 percent of an adult's surface area of 19,400 cm² (Foster and Chrostowski 1986) was exposed. Dermal absorption of the organic chemicals of potential concern was only evaluated for the bathing exposure scenario. Dermal absorption while showering and hence activities other than bathing is likely to result in minimal exposure based on the physical and chemical properties of the chemicals and the exposure assumptions (see Section 5.6.3.2 for further discussion).

The groundwater may be used for irrigation purposes. Thus, individuals or animals consuming crops irrigated with the contaminated groundwater could be exposed to chemicals present in the water. This indirect pathway for human exposure is incomplete. It is not known how much of the water used for gardening purposes is groundwater and how much is city water. Therefore, this pathway cannot be quantified.

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5.4.1.3 Surface Water

Neshaminy Creek is used for recreational purposes. There are boat docks along the creek in the area of the Croydon TCE Site. Individuals using the boats can come in contact with the surface water and sediments. Thus, exposure to these media will be evaluated in this assessment. Chemicals of potential concern were not selected for Neshaminy Creek surface water; therefore, only exposure to the potentially carcinogenic PAHs in sediments of Neshaminy Creek will be evaluated. The exposure point concentrations for this pathway are 2.27 mg/kg and 10.2 mg/kg for the average and plausible maximum cases, respectively.

Individuals also may be exposed to contaminants in the pond and Hog Run Creek. Access to the pond is difficult because the area surrounding it is overgrown with vegetation and littered with construction debris. Therefore, it is unlikely that human contact will occur with the surface water from this pond. Additionally, exposure via inhalation of compounds volatilizing from these surface water bodies will be limited because of the vegetative growth around these water bodies.

Access to portions of Hog Run Creek is also limited by heavy vegetation. However, some areas of the creek are accessible, and conceivably, children could use the creek as a play area. Because the water is very shallow, it is unlikely that children would swim in Hog Run Creek. But, children could wade in the creek and be exposed to the carcinogenic PAHs present in the sediments, and therefore this exposure pathway will be evaluated. The exposure point concentrations are 1.05 mg/kg and 2.56 mg/kg for the average and plausible maximum cases respectively.

Wildlife in the Croydon TCE Site area are likely to use all three surface water bodies. These wildlife are probably exposed to contaminants in these waters. These exposures will be discussed in the ecological risk assessment, Section 5.7.

5.4.1.4 Air

The soil at the Croydon TCE Site is a source of contaminants which can be transferred to the air (as discussed in Section 5.3). Most of the site, however, has been developed with houses, is paved, or vegetated with gardens or grass. The probability of significant releases of chemicals from these small areas is low. (No readings above background levels were detected on site with the HNU photoionization meter.) Based on the physiochemical properties of the soil chemicals of potential concern, it can be concluded that they are not likely to volatilize. Hence volatilization from soil is not considered to be a complete pathway.

The ball fields area is unvegetated in some parts and could act as a source of dust emissions. It is not possible, however, to quantify the release of dust generated while individuals are

playing ball during dry times of the year. For these reasons, this exposure pathway will also not be quantified.

The pond and Hog Run Creek were found to contain low levels of volatile organic chemicals. These water bodies can, therefore, act as sources of contaminants to the air. This pathway is not quantified, however, due to the vegetation surrounding these surface waters which limits the amount of material that can effectively migrate away from the sources. The residents living near these areas will not be significantly affected by these releases. Hence, this exposure pathway will not be quantified.

5.4.2 Site and Surrounding Area Under Future Use Conditions

In the absence of institutional controls limiting access or future uses of the Croydon TCE Site, there are additional exposure pathways that must be evaluated. Under current conditions, most of the water users within the study area are served by municipal water supplies. Private wells do exist on the site and some of the water from these wells is currently used for household and industrial purposes. It is possible that at some time in the future, a drinking water supply well or more residential wells could be put into operation at the site. Therefore, under future-use conditions, exposure to groundwater is still a complete pathway. It will be evaluated here using the monitoring well data.

Groundwater receptors at the Croydon TCE Site include both residential and industrial users. It is possible that, in the future, new companies will move into the area, existing firms could expand, or more residences be built. Future land use involving excavations for utilities or construction would create the potential for workers to be exposed to contaminated soils through dermal contact and subsequent incidental ingestion as well as through inhalation. This type of exposure would be short term compared with the exposure scenario developed for future residents under future-use conditions, below. Therefore, this scenario will not be quantified. If the areas of soil contamination were developed for residential purposes, residents could be exposed to soil contaminants while gardening or playing out of doors. Thus, this exposure pathway will be evaluated.

Surface water and sediment exposure pathways and point concentrations under future-use conditions are identical to those evaluated under current-use conditions. Therefore, these exposure pathways will not be reevaluated.

5.4.2.1 Groundwater

The groundwater at the Croydon TCE Site has been found to be contaminated. Monitoring well data can be used to evaluate future exposures to the groundwater chemicals of potential concern. These data are used because they provide a more accurate picture of the groundwater contamination at the site since the well construction and the depth of the well are

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known. Table 5-12 summarizes the concentrations of chemicals of potential concern in these wells. Exposure could occur via ingestion of the water. The exposure point concentrations for the ingestion of groundwater are those presented in Table 5-12.

Additional exposures could occur via inhalation and dermal contact from bathing or showering, washing clothes, cooking, washing dishes, and any other household activities which involve the use of water, as was discussed under the current-use scenario. In this public health evaluation, exposure via ingestion and inhalation and dermal contact while showering will be quantified. The methodology has been presented in Section 5.4.1.2 and will not be repeated here.

5.4.2.2 Soil

In the future, the ball field area could be developed for residential use. Should this occur, individuals could be exposed to soil contaminants throughout the time they live there. This exposure pathway is evaluated using the soil data from the ballfields, the River Road residence, and the River Road industrial area. The chemicals of potential concern in these areas are carcinogenic PAHs and PCBs. The exposure point concentrations for these areas are given in Table 5-4. As was the case for the current residential exposure pathway, it is conservatively assumed that the individual will reside at this residence for an entire lifetime and that the concentrations of the chemicals of potential concern remain constant over time. As a child, the individual will spend more time out of doors than will an adult. A lifetime average exposure of 100 and 160 days per year over a 70-year lifetime are assumed for the average and plausible maximum exposure case, respectively. The soil concentrations in Table 5-10 are used to evaluate this scenario.

5.5 TOXICITY CHARACTERIZATION

In this section, the chemicals of potential concern are characterized with respect to their potential toxicity to humans. The general methodology for the classification of health effects and the development of health effects criteria is described in Section 5.5.1 and provides the analytical framework for the characterization of human health impacts in Section 5.6. In Section 5.5.2, the concept of chemical-specific ARARs is introduced, and the types of standards, criteria, or guidance that may be classified as potential ARARs for the Croydon site are described and the values are presented. Finally, in Section 5.5.3, the toxicological properties of the chemicals of potential concern are discussed and the toxicological bases for the health effects criteria that will be used in the quantitative risk assessment are presented. The numerical values of the health effects criteria also are presented in tabular form.

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TABLE 5-12

CONCENTRATIONS OF CHEMICALS OF POTENTIAL CONCERN
IN THE MONITORING WELLS
CROYDON TCE SITE

Compound	Concentration (µg/liter)	
	Geometric Mean	Maximum
chloroform	0.15	8.9
4,4'-DDT	NA	0.77
1,1-dichloroethane	0.073	3.00
1,1-dichloroethene	0.16	75.0
dieldrin	0.080-	0.30
tetrachloroethene	0.091	4.1
1,1,1-trichloroethane	0.46	160
trichloroethene	1.05	420

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5.5.1 Human Health Effects Classification and Criteria Development

For risk assessment purposes, individual contaminants are separated into two categories of chemical toxicity depending on whether they exhibit carcinogenic or noncarcinogenic effects. This distinction relates to the currently-held scientific opinion that the mechanism of action for each category is different. For the purpose of assessing risks associated with potential carcinogens, EPA has adopted the scientific position that a small number of molecular events can cause changes in a single cell or a small number of cells that can lead to tumor formation. This is described as a no-threshold mechanism because it is assumed that there is essentially no level of exposure (i.e., a threshold) to a carcinogen that will not result in some finite possibility of causing the disease. In the case of chemicals exhibiting noncarcinogenic effects, however, it is believed that organisms have protective mechanisms that must be overcome before the toxic endpoint is reached. For example, if a large number of cells perform the same or similar functions, it would be necessary for significant damage or depletion of these cells to occur before an effect could be seen. This threshold view holds that a range of exposures from just above zero to some finite value can be tolerated by the organism without appreciable risk of causing the disease (EPA 1987a).

5.5.1.1 Human Health Effects Criteria for Potential Carcinogens

Cancer potency factors, developed by EPA's Carcinogen Assessment Group (CAG) for potentially carcinogenic chemicals, are derived from the results of human epidemiological studies or chronic animal bioassays. Potency factors are expressed in units of (mg/kg/day)⁻¹. The animal studies on which some potency factors are based must usually be conducted using relatively high doses to detect possible adverse effects. Because humans are expected to be exposed at lower doses than those used in the animal studies, the data are adjusted by using mathematical models. The data from animal studies are fitted to the linearized multistage model to obtain a dose-response curve. The low-dose slope of the dose-response curve is subjected to various adjustments, and an interspecies scaling factor is applied to derive the cancer potency factor for humans. Dose-response data derived from human epidemiological studies are fitted to dose-time-response curves on an individual basis.

EPA assigns weight-of-evidence classifications to potential carcinogens. Under this system, chemicals are classified as either Group A, Group B1, Group B2, Group C, Group D, or Group E. Group A chemicals (human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer. Groups B1 and B2 chemicals (probable human carcinogens) are agents for which there is limited (B1) or inadequate (B2)

evidence of carcinogenicity from human studies but for which there is sufficient evidence of carcinogenicity from animal studies. Group C chemicals (possible human carcinogens) are agents for which there is limited evidence of carcinogenicity in animals, and Group D chemicals (not classified as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available. Group E chemicals (evidence of non-carcinogenicity in humans) are agents for which there is no evidence in adequate human or animal studies of carcinogenicity.

The cancer potency factor is used to estimate the upper bound excess lifetime carcinogenic risk associated with low-dose exposure to a potential carcinogen. Cancer potency factors derived from animal studies using the linearized multistage model typically provide 95 percent upper-bound estimates of excess lifetime cancer risks. Whereas the actual risks may be unlikely to be higher than those estimated risks, they could be considerably lower. Cancer potency factors derived from high-dose human epidemiological studies are typically also intended to provide upper bounds of lifetime excess cancer risks.

5.5.1.2 Human Health Effects Criteria for Noncarcinogens

Health criteria for chemicals exhibiting noncarcinogenic effects are generally developed using risk reference doses (RfDs) developed by the EPA RfD Work Group or RfDs obtained from Health Effects Assessments (HEAs) or from the Office of Drinking Water analysis in support of health-based drinking water standards. The RfD, expressed in units of mg/kg/day, is an estimate of the daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs usually are derived from human studies involving workplace exposures or from animal studies and are adjusted using uncertainty factors. The RfD provides a benchmark to which lifetime or long-term chemical intakes by other routes (e.g., via exposure to contaminated environmental media) may be compared.

5.5.2 Applicable or Relevant and Appropriate Requirements (ARARs)

EPA's guidance on ARARs (EPA 1987b) defines ARARs as follows:

Applicable requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

"Applicability" implies that the remedial action or the circumstances at the site satisfy all of the jurisdictional prerequisites of a requirement.

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Relevant and appropriate requirements means those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. The relevance and appropriateness of a requirement can be judged by comparing a number of factors, including the characteristics of the remedial action, the hazardous substances in question, or the physical circumstances of the site, with those addressed in the requirement. It is also helpful to look at the objective and origin of the requirement. For example, while RCRA regulations are not applicable to closing undisturbed hazardous waste in place, the RCRA regulation for closure by capping may be deemed relevant and appropriate.

A requirement that is judged to be relevant and appropriate must be complied with to the same degree as if it were applicable. However, there is more discretion in this determination: it is possible for only part of a requirement to be considered relevant and appropriate, the rest being dismissed if judged not to be relevant and appropriate in a given case.

Non-promulgated advisories or guidance documents issued by Federal or State governments do not have the status of potential ARARs. However, they may be considered in determining the necessary level of cleanup for protection of health or environment.

Only those ARARs or advisories or guidance that are ambient or chemical-specific requirements [i.e., those requirements which "set health or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants" (EPA 1987b)], as opposed to ARARs which are classified as action-specific or locational requirements, are used in risk assessment.

No Federal or state chemical-specific ARARs or guidance are available for the chemicals of potential concern in the soil, sediment, or surface water at the Croydon TCE Site. Federal ARARs are available for the chemicals of potential concern in groundwater; however, and those that are considered pertinent to the public health evaluation for the Croydon site are presented in Table 5-13 and are discussed below.

According to EPA's interim guidance on ARARs, Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act (SDWA) are generally applicable or relevant and appropriate standards for water that is or may be used for drinking water source. The groundwater at the Croydon site is currently used as a drinking water source and therefore MCLs will be used as ARARs at this site.

TABLE 5-13

POTENTIAL ARARS FOR THE CHEMICALS OF POTENTIAL CONCERN
IN THE GROUNDWATER
CROYDON TCE SITE

Chemical	Criterion (µg/liter)		
	MCLG(a)	MCL(b)	Other(c)
chloroform	--	100(d)	NA
DDT	--	--	0 (1.2x10 ⁻³)
1,1-dichloroethane	--	--	NA
1,1-dichloroethene	7	7	NA
dieldrin	--	--	0 (1.1x10 ⁻³)
tetrachloroethene	0(e)	--	NA
1,1,1-trichloroethane	200	200	NA
trichloroethene	0	5	NA

- (a) Maximum Contaminant Level Goal. MCLGs are non-enforceable goals which are set at levels which would result in no known or anticipated adverse health effects with an adequate margin of safety.
- (b) Maximum Contaminant Level. MCLs are enforceable standards that are set as close to MCLGs as is feasible after consideration of treatment technologies, costs, availability of analytical methods, and other factors.
- (c) Ambient Water Quality Criteria, adjusted for drinking water only, are used as ARARS for those chemicals for which no MCL or MCLG exists. Value in parenthesis is the ambient water concentration corresponding to a 10⁻⁶ excess lifetime cancer risk assuming a person drinks 2 liters of water/day and weighs 70 kg.
- (d) Standard is for total trihalomethanes.
- (e) proposed.
- This criterion has not been developed for this chemical.
- NA Not Applicable; other criteria, such as adjusted AWQC, are used as ARARS only for those chemicals for which neither MCLs or MCLGs are available.

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Maximum Contaminant Level Goals (MCLGs), also established under the SDWA, are additional chemical-specific standards which may be considered to be applicable or relevant and appropriate. The MCLs and MCLGs for the chemicals of potential concern in groundwater are listed in Table 5-13. EPA intends to propose MCLs and MCLGs for 39 chemicals in the Summer of 1988. These criteria may be ARARs at that time and if so, will be included in the Phase II public health evaluation. Ambient Water Quality Criteria (AWQC) adjusted for drinking water intake only can also be used as ARARs for groundwater exposures, but because some of these criteria are based on older studies, caution must be exercised in using them; when based on the most recent information these adjusted values are usually equal to the MCLGs. In this assessment, adjusted AWQC will be used as ARARs for comparison to groundwater concentrations only for those chemicals of potential concern for which neither MCLs or MCLGs are available.

Generally, MCLs and MCLGs for toxic chemicals represent the allowable lifetime exposure to the contaminant for a 70-kg adult who is assumed to ingest 2 liters of water per day for a lifetime. MCLGs are non-enforceable goals which are set at levels which would result in no known or anticipated adverse health effects with an adequate margin of safety. MCLs are enforceable standards set as close to MCLGs as possible, but in addition to health factors, MCLs are required by law to reflect the technological and economic feasibility of removing the contaminant from the water supply. The limit set must be feasible given the best available technology and treatment techniques (EPA 1986a).

5.5.3 Toxicity of the Chemicals of Potential Concern and Health Effects Criteria for Use in Risk Evaluation

Table 5-14 presents the health effects criteria that will be used to evaluate potential health risks posed by noncarcinogenic and carcinogenic chemicals of potential concern at the Croydon site. Criteria are presented for inhalation and oral routes, when available. Some noncarcinogens do not have an RfD developed specifically for inhalation exposures. In these instances, the RfD derived using the oral exposure route will be used to assess inhalation exposures. This is done because for the chemicals lacking inhalation RfDs, the systemic toxic effects are the same following either oral or inhalation exposures. Potential carcinogenic risks are evaluated using the oral potency factor for all pathways if an inhalation potency factor is not available. Equivalent absorption of inhaled and ingested chemical and similarity of potency via inhalation and oral exposure is assumed.

Below, the toxicological properties of the chemicals of potential concern and the toxicological basis for the health effects criteria presented in Table 5-14 are briefly discussed.

TABLE 5-14

HUMAN HEALTH EFFECTS CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN
CROYDON TCE SITE

Chemical	Reference Dose (RfD)(a) (mg/kg/day)		Cancer Potency Factor(b) (mg/kg/day) ⁻¹		Carcino- genicity Weight of Evidence(c)
	Oral	Inhalation	Oral	Inhalation	
chloroform	1.0 x 10 ⁻²	--	8.1 x 10 ⁻²	8.1 x 10 ⁻² (d)	B2
1,1-dichloroethane	1.2 x 10 ⁻¹ (f)	1.3 x 10 ⁻¹	9.1 x 10 ⁻² (g)	--	D
1,1-dichloroethene	9.0 x 10 ⁻³	--	6.00 x 10 ⁻¹	1.2	C
DDT/DDE/DDD(h)	5.0 x 10 ⁻⁴	--	3.4 x 10 ⁻¹	--	B2
dieldrin	--	--	30	--	B2
PAHs (carcinogenic)(i)	--	--	11.5	6.1	B2
PCBs	--	--	7.7(j)	--	B2
tetrachloroethene	2.0 x 10 ⁻²	1.5	5.1 x 10 ⁻²	3.3 x 10 ⁻²	B2
1,1,1-trichloroethane	9.0 x 10 ⁻²	3.1	--	--	D
trichloroethene	--	--	1.1 x 10 ⁻²	4.6 x 10 ⁻³ (k)	B2

- (a) Except where noted, verified reference dose developed by EPA and reported in EPA, 1987c or EPA, 1987d.
- (b) Cancer potency factors developed by EPA's Carcinogen Assessment Group and reported in EPA, 1987c or EPA, 1987d.
- (c) EPA carcinogenic weight-of-evidence classification. See text for description of categories.
- (d) Value in the Health Assessment Document for this chemical (EPA, 1985c).
- (e) As reported in EPA, 1987e.
- (f) RfD reported in Health Effects Assessment for this chemical (EPA, 1984b).

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TABLE 5-14
HUMAN HEALTH EFFECTS CRITERIA FOR CHEMICALS OF POTENTIAL CONCERN
CROYDON TCE SITE
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- (g) The oral cancer potency factor for 1,1-dichloroethane is based on structure activity relationships to 1,2-dichloroethane (EPA, 1988a).
- (h) Toxicity criteria values are derived for DDT.
- (i) Potency factors are for benzo(a)pyrene and are currently being reviewed by EPA based on a re-analysis of the available data.
- (j) EPA (1988b).
- (k) Potency factor reported in Health Effects Assessment for this chemical (EPA, 1984c).

5.5.3.1 Chloroform

Chloroform has been reported to induce renal epithelial tumors in rats and hepatocellular carcinomas in mice. Suggestive evidence from human epidemiological studies indicates that exposure to chloroform and other trihalomethanes in water supplies may be associated with an increased incidence of bladder tumors. In humans, acute exposures to chloroform may result in death caused by ventricular fibrillation. Chronic exposure may lead to hepatic, renal, and cardiac effects and central nervous system depression.

Chloroform has been classified by EPA as Group B2--Probable Human Carcinogen. EPA (1985c) developed a cancer potency factor of $8.1 \times 10^{-2} \text{ (mg/kg/day)}^{-1}$ for both ingestion and inhalation exposure to chloroform. These values were based on the results of a bioassay in mice treated by gavage with chloroform in corn oil five times weekly for 78 weeks (NCI 1976a). Hepatocellular carcinomas were significantly increased in both males and females. The cancer potency and weight-of-evidence classification of chloroform is currently being reevaluated by EPA. EPA (1987c) also has derived an oral RfD for chloroform based on a chronic bioassay in dogs (Heywood et al. 1979). The RfD is 0.01 mg/kg/day based on a LOAEL in which liver effects were observed following oral exposure to chloroform.

5.5.3.2 4,4'-DDT/DDD/DDE

4,4'-DDD and 4,4'-DDE are metabolic products of 4,4'-DDT. The majority of toxicity information is available on 4,4'-DDT. 4,4'-DDT has been shown to be carcinogenic to mice, with the principal site of action being the liver. Increased incidences of tumors of the lung and lymphatic system also have been reported. 4,4'-DDT is a reproductive toxicant, and has caused reduced fertility, reduced growth of offspring, and fetal mortality in mice and rats. Chronic exposures caused adverse effects in the liver and central nervous system of experimental animals. Both acute and chronic exposures can induce seizures.

EPA has classified 4,4'-DDT and its metabolites in Group B2--Probable Human Carcinogen. An oral cancer potency factor of $0.34 \text{ (mg/kg/day)}^{-1}$ has been developed by EPA (1984a, 1987d) for 4,4'-DDT. The value is based on several bioassays in which an increased incidence of tumors was observed in mice and rats. A geometric average of the potency values from each of the carcinogenicity studies resulted in the final potency factor. EPA (1987c) developed an oral RfD for 4,4'-DDT of $5.0 \times 10^{-4} \text{ mg/kg/day}$. The value is based on a feeding study in rats in which liver toxicity was observed in animals fed 4,4'-DDT in the diet at concentrations of 5 ppm or greater (Laung et al. 1950). No effects were observed in animals fed 1 ppm 4,4'-DDT in the diet.

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5.5.3.3 1,1-Dichloroethane

Few toxicity data are available on 1,1-dichloroethane. Marginal increases in mammary gland adenocarcinomas and in hemangiosarcomas were observed in female rats exposed to the chemical. However, because of study deficiencies, these results provide inconclusive evidence of the carcinogenic potential of the 1,1-dichloroethane. Based on analogy to other chlorinated aliphatics, it is probable that human exposure to sufficiently high levels of 1,1-dichloroethane would cause central nervous system depression and respiratory tract and skin irritation, although no dose-response data concerning these effects are available. Renal damage and retarded fetal development have been observed in animals exposed by inhalation.

1,1-dichloroethane has not been assigned a carcinogenicity weight-of-evidence classification by EPA. However, EPA (1987d) reported an oral cancer potency factor for 1,1-dichloroethane of 9.1×10^{-2} (mg/kg/day)⁻¹. This potency factor is based on a structure-activity relationship to 1,2-dichloroethane, a Group B2 carcinogen (EPA 1988a). EPA (1984b) also developed oral and inhalation RfDs of 0.12 mg/kg/day and 0.138 mg/kg/day based on a subchronic study in which cats were exposed for 26 weeks to 500 ppm 1,1-dichloroethane or, for 2 consecutive 13-week periods to 500 ppm and then 1,000 ppm 1,1-dichloroethane via inhalation (Hoffman et al. 1971). No effects were observed in the group exposed to 500 ppm 1,1-dichloroethane only, but cats exposed to 500 ppm and then 1,000 ppm experienced renal damage.

5.5.3.4 1,1-Dichloroethene

1,1-dichloroethene is a central nervous system depressant. Chronic low-level exposure to this substance may result in neurotoxicity, nephrotoxicity, hepatotoxicity, and cardiac arrhythmia. Inhalation or oral exposure of rats and rabbits has produced fetotoxicity and minor skeletal abnormalities, but only at doses maternally toxic. 1,1-Dichloroethene caused kidney tumors and leukemia in a single study of mice exposed by inhalation, but the results of other studies were equivocal or negative.

EPA has classified 1,1-dichloroethene as Group C--Possible Human Carcinogen, and has developed inhalation and oral cancer potency factors of 1.2 (mg/kg/day)⁻¹ and 0.6 (mg/kg/day)⁻¹, respectively (EPA 1985d, 1987c). The inhalation potency factor was based on the increased incidence of renal adenocarcinomas in male mice exposed via inhalation for 4 hours/day, 4-5 days/week to 1,1-dichloroethene for 52 weeks and observed for a total of 121 weeks (Maltoni et al. 1985). The oral potency factor was derived by estimating an upper-limit value from negative bioassay data and assuming that a carcinogenic response occurs via ingestion, although there is no direct evidence that this is true. EPA (1987c) developed an oral RfD of 9×10^{-3} mg/kg/day based on the occurrence of hepatic lesions in rats chronically

exposed to 1,1-dichloroethene in drinking water (Quast et al. 1983).

5.5.3.5 Dieldrin

Dieldrin is carcinogenic in mice and has induced dose-related increases in the incidence of hepatocellular carcinomas following exposure in the diet. Chronic oral exposure in experimental animals also has been associated with liver and kidney effects and convulsions. Effects in humans following acute exposure include malaise, incoordination, headache, dizziness, gastrointestinal disturbances, and major motor convulsions.

EPA has classified dieldrin as Group B2--Probable human carcinogen. An oral cancer potency factor of 30 (mg/kg/day)⁻¹ was derived based on the increased incidence of hepatocellular carcinomas in female mice given dieldrin in the diet for 924 days (EPA 1987d, Walker et al. 1972).

5.5.3.6 Polychlorinated Biphenyls (PCBs)

Several bioassays have documented the carcinogenicity of PCB mixtures. In addition, PCBs have been shown to reduce reproductive success in monkeys and mink. Human epidemiological evidence suggests that reproductive toxicity also may occur in humans, although the evidence is inconclusive. PCBs also have caused immunotoxic and immunosuppressive effects in experimental animals exposed to the compounds via the diet.

EPA has classified PCBs in Group B2--Probable Human Carcinogen, and has developed a low-level cancer potency factor for PCBs of 7.7 (mg/kg/day)⁻¹ (EPA 1988b). The basis for this potency factor has not yet been published, although it is known to be based on a rodent study using Aroclor 1260.

5.5.3.7 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are often separated into two categories for the purposes of risk assessment: carcinogenic and noncarcinogenic PAHs. Carcinogenic PAHs are believed to induce tumors both at the site of application and systemically. This group of PAHs also has been shown to have immunosuppressive effects in animals. Carcinogenic PAHs can produce noncarcinogenic effects, but at concentrations much higher than those that elicit a significant carcinogenic response. For noncarcinogenic PAHs, the primary acute effect is dermatitis. Some noncarcinogenic PAHs have been shown to cause systemic toxicity but usually only at relatively high doses.

EPA has classified carcinogenic PAHs as either Group B2 or Group C carcinogens and has developed inhalation and oral potency factors of 11.5 (mg/kg/day)⁻¹ and 6.1 (mg/kg/day)⁻¹ for benzo(a)pyrene, one of the most potent carcinogens (EPA 1987d). The inhalation potency factor was based on a

treatment-related increase of tumors of the nasal cavity, larynx, trachea, and pharynx in hamsters exposed to B(a)P in air (Thyssen et al. 1981). The oral potency factor was based on increased gastric tumors, pulmonary adenomas, and leukemia in mice fed B(a)P (Neal and Rigdon 1967). These potency factors are currently undergoing a reevaluation by EPA based on recalculation of the data. Carcinogenic PAHs detected at the Croydon TCE Site are benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and benzo(a,h)anthracene.

5.5.3.8 Tetrachloroethene

Tetrachloroethene has induced carcinogenic responses in both mice and rats. Principal toxic effects in humans from both acute and chronic exposures include central nervous system depression and liver and kidney damage. Teratogenic effects, including subcutaneous edema and delayed ossification of skull bones and sternebrae, also have been observed in the offspring of mice exposed to tetrachloroethene during gestation.

The carcinogenicity weight-of-evidence classification for tetrachloroethene is currently under review by EPA. The oral and inhalation cancer potency factors of $0.051 \text{ (mg/kg/day)}^{-1}$ and $0.003 \text{ (mg/kg/day)}^{-1}$, respectively, (EPA 1987d) also are under review. The oral potency factor was derived based on an increased incidence of hepatocellular carcinomas in female mice exposed by gavage to tetrachloroethene in corn oil 5 days/week for 78 weeks (NCI 1977). The basis for the inhalation potency factor has not yet been published. EPA (1987c) derived an oral reference dose of 0.02 mg/kg/day for tetrachloroethene based on an inhalation study in rats exposed for 7 months to concentrations of 70 ppm, 230 ppm or 470 ppm of the compound in air (Carpenter 1937). No effects were observed in animals exposed to 70 ppm (19.4 mg/kg/day). Renal and liver effects were observed in the higher dose groups.

5.5.3.9 1,1,1-Trichloroethane

The principal effects of exposure to 1,1,1-trichloroethane in humans and experimental animals are central nervous system depression, including anesthesia at very high concentrations, and impairment of coordination, equilibrium, and judgment at lower concentrations. Cardiovascular effects, including premature ventricular contractions and decreased blood pressure can result from exposure to high concentrations of 1,1,1-trichloroethane. Several bioassays have investigated the carcinogenicity of 1,1,1-trichloroethane but the resulting data are not of sufficient quality to determine the carcinogenic potential of 1,1,1-trichloroethane.

EPA developed acceptable oral and inhalation intake levels of 0.09 mg/kg/day (EPA 1987c) and 3.1 mg/kg/day (EPA 1987c) respectively, for 1,1,1-trichloroethane. The oral value was based on an inhalation study in guinea pigs in which fatty

livers and increased liver weights were observed in animals exposed to 1,1,1-trichloroethene concentrations greater than 500 ppm (90 mg/kg/day) (Torkelson et al. 1958). The basis of the inhalation value has not yet been published.

5.5.3.10 Trichloroethene

Trichloroethene has caused carcinogenic responses in rats exposed by gavage and in mice exposed by inhalation. Trichloroethene also acts as a central nervous system depressant following both acute and chronic exposure by both ingestion and inhalation. Occupational exposure to concentrated trichloroethene vapors may result in dermatitis.

EPA has classified trichloroethene in Group B2--Probable Human Carcinogen. Cancer potency factors of $0.011 \text{ (mg/kg/day)}^{-1}$ and $0.013 \text{ (mg/kg/day)}^{-1}$ have been developed for oral and inhalation exposures, respectively (EPA 1987c). These values are based on an increased incidence of liver tumors in mice exposed by gavage (NCI 1976b, NTP 1983).

5.6 HUMAN RISK CHARACTERIZATION

According to guidelines for preparing risk assessments as part of the RI/FS process (EPA 1986a), the potential adverse effects on human health should first be assessed where possible by comparing chemical concentrations found in environmental media at or near the site with applicable or relevant and appropriate requirements (ARARs) or other guidance that has been developed for the protection of human health or the environment. If ARARs are not available for all chemicals and exposures considered, quantitative risk estimates must be developed in addition to the comparison to ARARs.

5.6.1 Comparison With Applicable or Relevant and Appropriate Requirements (ARARs)

In this section, the concentrations of chemicals of potential concern in groundwater at the Croydon TCE Site are compared to ARARs. Table 5-15 presents this comparison. As the Table indicates, ARARs for some chemicals are exceeded. In the residential wells, the maximum concentration of trichloroethene exceeds its MCL. In the monitoring wells, the maximum concentration of trichloroethene exceeds its MCL, and the maximum concentration of 1,1-dichloroethene exceeds its MCL and MCLG.

The mean and maximum concentrations of dieldrin in the monitoring wells exceed the AWQC for this chemical corresponding to the 10^{-6} excess lifetime cancer risk level. In both the residential and monitoring wells, the mean and maximum concentrations of tetrachloroethene exceed the proposed MCLG of zero.

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TABLE 5-15

COMPARISON OF ARARS WITH THE GROUNDWATER FOR THE CHEMICALS OF POTENTIAL CONCERN
CROYDON TCE SITE

Chemical	Criterion (µg/liter)			Well Concentration (µg/l)			
	MCLG(a)	MCL(b)	Other(c)	Residential Wells	Monitoring Wells		
chloroform	--	100(d)	NA	Geometric Mean	Maximum	Geometric Mean	Maximum
DDT	--	--	470	ND	ND	NM	0.77
1,1-dichloroethane	--	--	NA	0.044	2.97	0.07	3.0
1,1-dichloroethene	7	--	NA	0.077	5.122	0.16	75
dieldrin	--	--	0 (1.1x10 ⁻³)	ND	ND	0.09	0.3
tetrachlorethene	0(e)	--	NA	0.069	4.3	0.09	4.1
1,1,1-trichloroethane	200	200	NA	0.14	75	0.46	160
trichloroethene	0	5	NA	0.74	97	1.1	420

- (a) Maximum Contaminant Level Goal. MCLGs are non-enforceable goals which are set at levels which would result in no known or anticipated adverse health effects with an adequate margin of safety.
- (b) Maximum Contaminant Level. MCLs are enforceable standards that are set as close to MCLGs as is feasible after consideration of treatment technologies, costs, availability of analytical methods, and other factors.
- (c) Ambient Water Quality Criteria, adjusted for drinking water only, are used as ARARs for those chemicals for which no MCL or MCLG exists. Value in parentheses is the ambient water concentration corresponding to a 10⁻⁶ excess lifetime cancer risk assuming a person drinks 2 liters of water/day and weighs 70 kg.
- (d) Standard is for total trihalomethanes.
- (e) proposed.
- This criterion has not been developed for this chemical.
- NA Not Applicable; other criteria, such as adjusted AWQC, are used as ARARs only for those chemicals for which neither MCLs or MCLGs are available.
- ND Not detected in these wells.
- NM Geometric mean was not calculated due to only one positive detect.

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5.6.2 Quantitative Risk Characterization

To quantitatively assess the risks to human health associated with the current-use and future-use exposure scenarios considered in this assessment, the concentrations of chemicals in relevant environmental media (exposure point concentrations) presented in Section 5.2 are converted to chronic daily intakes (CDIs). CDIs are the amount of a substance taken into the body per unit body weight per unit time, expressed in units of mg/kg/day. A CDI is averaged over a lifetime for carcinogens (EPA 1986b) and over the exposure period for noncarcinogens (EPA 1986c).

For potential carcinogens, excess lifetime cancer risks are obtained by multiplying the daily intake of the contaminant under consideration by its cancer potency factor. This is appropriate for cancer risks of 10^{-2} (i.e., 1 excess cancer in every 100 individuals exposed throughout their lifetime) or less. EPA recommends that the total cancer risk to individuals resulting from exposure at a Superfund site be reduced to zero where possible (EPA 1986a). EPA has implemented actions under Superfund associated with total cancer risks ranging from 10^{-4} to 10^{-7} (EPA 1986a). A risk level of 10^{-6} , which represents the probability of one in one million of a person contacting cancer from exposure to the potential carcinogen, is often used as a benchmark by regulatory agencies. Accordingly, 10^{-6} will be the target risk level used in this report. However, remedies will be developed which reduce risks to 10^{-4} , 10^{-5} , or 10^{-7} . In general, EPA cancer potency factors based on animal data (e.g., PAHs) are 95 percent upper-confidence limit, values based on the linearized multistage model. Thus, the actual risks associated with exposure to a potential carcinogen-quantitatively evaluated based on animal data, are not likely to exceed the risks estimated using these cancer potency factors, but may be lower. EPA cancer potencies based on human data (e.g., arsenic) are point estimates based on a linear absolute risk model. In its Health Assessment Document for Arsenic (EPA 1984d), the Agency notes that "while it is unlikely that the true risks would be higher than these estimates, they could be substantially lower."

Potential risks are presented for noncarcinogens as the ratio of the chronic daily intake exposure to the reference dose (CDI:RfD). The sum of all of the ratios of chemicals under consideration is called the hazard index. The hazard index is useful as a reference point for gauging the potential effects of environmental exposures to complex mixtures. In general, hazard indices that are less than 1 are not likely to be associated with any health risks and are therefore less likely to be of regulatory concern than hazard indices greater than 1. If the hazard index for all noncarcinogens exceeds 1, it should be recalculated separately for noncarcinogens grouped according to target organ toxicity. Hazard indices which exceed 1 for these groupings may indicate the potential for toxic effects. A conclusion should not be categorically drawn, however, that all

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hazard indices less than 1 are "acceptable." This is a consequence of the perhaps one-order-of-magnitude or greater uncertainty inherent in estimates of the RfD and CDI, in addition to the fact that the uncertainties associated with the individual terms in the hazard index calculation are additive.

In accordance with EPA's guidelines for evaluating the potential toxicity of complex mixtures (EPA 1986d), it was assumed that the toxic effects of the contaminants of concern would be additive. Thus, lifetime excess cancer risks and the CDI:RfD ratios were summed to indicate the potential risks associated with mixtures of potential carcinogens and noncarcinogens, respectively. In the absence of specific information on the toxicity of the mixture to be assessed or on similar mixtures, EPA guidelines generally recommend assuming that the effects of different components on the mixtures are additive when affecting a particular organ or system. Synergistic or antagonistic interactions may be taken into account if there is specific information on particular combinations of chemicals. In this risk assessment, it was assumed that the effects of the contaminants of concern were additive.

In this section of the risk assessment, the intakes of chemicals of potential concern by potentially-exposed populations are first calculated. To determine these intakes, assumptions are made concerning chemical concentrations, exposed populations, and exposure conditions, such as frequency and duration of exposure. For each exposure scenario evaluated, two exposure cases--an average case and plausible maximum case--are considered. For the average exposure case, geometric mean concentrations are used together with what are considered to be the most likely (although conservative) exposure conditions. For the plausible maximum case, the highest measured concentrations are used together with high estimates of the range of potential exposure parameters relating to the frequency/duration of exposure and quantity of contaminated media contacted. It should be noted that the exposure assumptions used for the plausible maximum case, while considered possible, are likely to apply only to a very small segment of the potentially exposed populations.

Chronic daily intakes, excess lifetime cancer risks, and CDI:RfD ratios for the site-related chemicals considered in this assessment, as well as the assumptions and procedures used to calculate these values, are shown below for each scenario evaluated.

5.6.3 Estimate of Exposure and Assessment of Risk Under Current Conditions

In this section, exposure point concentrations are used to estimate the extent of human exposure to the chemicals of potential concern under the current use conditions at the Croydon TCE Site. As has been discussed in Section 5.4, 5.5, and 5.6, exposure pathways that may have a potential impact on human

health under current use conditions include: direct contact with contaminated soils in the ballfield and at the residence along River Road, ingestion; inhalation; dermal absorption of contaminants in or released from groundwater; and direct contact with contaminated sediments.

An average and a plausible, maximum-exposure case are estimated for each exposure pathway evaluated. Conservative assumptions are used to determine these exposures in the absence of definitive data. Conservative assumptions tend to overestimate exposure so that the final estimate of exposure will be near or higher than the upper end of the range of actual exposure. Exposures and risks for each of these pathways are discussed below.

5.6.3.1 Direct Contact with Contaminated Soil

Direct contact with contaminated soil is considered most likely to involve adults playing baseball on the ballfield adjacent to the Mary Devine School or individuals living at the River Road residence. Direct contact with the contaminated soil may result in dermal contact and absorption of contaminants through the skin, as well as incidental ingestion of the compounds during activities such as mouthing, smoking, or eating. These exposures are quantified below.

For the exposure scenario involving baseball players, it is assumed under the average case that individuals play baseball twice weekly for 3 months each year for 5 years. For the plausible maximum case, it is assumed that individuals play baseball 5 times weekly for 5 months each year for 20 years. EPA standard assumptions for average lifetime (70 years) and adult body weights (70 kg) were used (EPA 1985a).

Average and plausible maximum incidental ingestion rates of 50 and 100 mg/visit are used based on the work of Lagoy (1987). Contact rates of 1 g/visit and 3 g/visit are used as the average and plausible maximum estimates of soil contact rates for dermal exposure. These rates are based on a range of soil contact rates presented by Schaum (1984) (0.5-1.5 mg/cm²) and the surface area of the body that is likely to be in contact with the soil (e.g., approximately 2,000 cm² for the hands and forearms) reported in EPA (1985a). These are reasonable values, but they are another source of uncertainty in the risk calculation.

The PCBs and PAHs present in the soil are likely to be strongly sorbed to the soil, and consequently may be less bioavailable than these same chemicals in drinking water or animal feed (typical media in animal studies used to derive toxicity criteria). For PCBs for example, several studies were located in reviews by Drill et al. (1981) and EPA (1985f) which lead to the conclusion that >90 percent of PCBs are absorbed from food. Although there is some evidence in these reviews that absorption is congener-specific, a value of 100 percent is reasonable for

this route. If the PCBs are adsorbed onto soil, we can expect a range of bioavailability from 15 to 50 percent based on analogy with dioxin (VandenBerg et al. 1983, 1987; Umbreit et al. 1986). A similar range of values can be anticipated for PAHs based upon similarity of physical and chemical properties with PCBs. In this assessment, a bioavailability factor of 15 percent will be used for PCBs and PAHs for the average case and a factor of 50 percent will be used for the plausible maximum case.

For dermal absorption, no empirical data are available on PCB and PAH absorption from soil. For PCB absorption from soil, a value of 7 percent is used. This value is derived from the solvent absorption work of Wester et al. 1987 and a ratio of TCDD absorbed from solvent to that from soil as reported in Poiger and Schlatter (1980). This value is based on the average solvent absorption of TCDD as reported in this paper. For PAH absorption from soil, a value of 5 percent is used. This value is derived from a study by Feldman and Maibach (1974) in which methylchloranthrene, a PAH, was absorbed through human forearm skin when applied in acetone. Twenty-four hours after application, 5 percent of the total applied dose was absorbed. This value probably overestimates the amount of PAHs which would be dermally absorbed from soil because the experimental conditions probably promoted greater dermal absorption (e.g., use of acetone carrier) than would be expected from environmental exposure. However, the 5 percent value will be used in this assessment to provide a conservative estimate of exposure.

Using these assumptions, the average and plausible maximum chronic daily intakes (CDIs) for baseball players were derived and are presented in Table 5-16, along with the associated potential carcinogenic risks. The lifetime excess upper bound cancer risk is 6×10^{-8} under the average case and 4×10^{-6} under the plausible maximum case.

Direct contact by River Road residents living on the River Road property might be exposed to contaminants in the soils during outdoor activities. Table 5-17 summarizes the average and plausible, maximum exposure assumptions used in this evaluation. These assumptions are derived from the same sources as mentioned above for the baseball player, direct contact scenario, but differ in that they are average lifetime exposures. Time-weighted averages for the amount of soil ingested per exposure event, the dermal soil contact rate, and an individual's body weight were calculated and used to quantitatively evaluate exposure of onsite residents over a lifetime. Using these assumptions, the average and plausible maximum CDIs for residents of the River Road area were derived and are presented in Table 5-18, along with the associated potential carcinogenic risks. The lifetime excess upperbound cancer risk is 9×10^{-6} under the average case and 3×10^{-4} under the plausible maximum case.

AR300471

TABLE 5-16
EXPOSURES AND RISKS ASSOCIATED WITH CONTACT OF SOILS
AT THE BASEBALL FIELD BY PLAYERS
CROYDON TCE SITE

Compound	Potential Carcinogenic Risks										
	Soil Concentration (mg/kg)		Quantity of Chemical Ingested and Absorbed via Ingestion (mg/kg/day)		Quantity of Chemical Dermal Absorbed (mg/kg/day)		Chronic Daily Intake, Based on A Lifetime Exposure (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum		Average	Plausible Maximum
PAHs (a)	1.26E+00	1.53E+00	6.34E-10	7.70E-08	4.18E-09	2.54E-07	4.82E-09	3.31E-07	1.15E+01	6E-08	4E-06
PCBs (b)	4.88E-02	2.90E-01	2.46E-11	1.46E-08	2.27E-10	6.74E-08	2.51E-10	8.20E-08	7.70E+00	2E-09	6E-07
TOTAL										6E-08	4E-06

(a) Carcinogenic polynuclear aromatic hydrocarbons

(b) Total polychlorinated biphenyls

AR300472

TABLE 5-17

ASSUMPTION FOR USE IN RISK ASSESSMENT FOR DIRECT CONTACT
BY CURRENT RESIDENTS WITH SOILS
CROYDON TCE SITE

Parameters	Average Exposure	Maximum Exposure
Frequency of Exposure	100 days/year	168 days/year
Duration of Exposure	70 years	70 years
Average Weight ^a	63 kg	63 kg
Incidental Ingestion Rate ^a	54 mg/day	145 mg/day
Percent PAHs and PCBs Absorbed from Ingested Soils	15%	45%
Soil Contact Rate ^a	0.79 g/day	5.4 g/day
Percent PAHs Absorbed Dermally from Skin	5%	5%
Percent PCBs Absorbed Dermally from Skin	7%	7%
Average Lifetime	70 years	70 years

^a Based on lifetime average exposure assumptions.

AR300473

TABLE 5-18
EXPOSURES AND RISKS ASSOCIATED WITH CONTACT OF SOILS BY CURRENT RESIDENTS
CROYDON TCE SITE
POTENTIAL CARCINOGENIC EFFECTS

Compound	Soil Concentration (mg/kg)		Quantity of Chemical Ingested and Absorbed via Ingestion (mg/kg/day)		Quantity of Chemical Dermal Absorption (mg/kg/day)		Chronic Daily Intake, based on a Lifetime Exposure (mg/kg/day)		Potency Factor (mg/kg/day) ¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum		Average	Plausible Maximum
CPAHs (a)	3.71E+00	1.19E+01	1.31E-07	5.67E-06	6.37E-07	2.35E-05	7.68E-07	2.91E-05	1.15E+01	9E-06	3E-04
PCBs (b)	2.31E-01	2.95E-01	8.14E-09	1.41E-07	5.56E-08	8.15E-07	6.37E-08	9.55E-07	7.70E+00	5E-07	7E-06
TOTAL	---	---	---	---	---	---	---	---	---	9E-06	3E-04

(a) Carcinogenic polynuclear aromatic hydrocarbons.
(b) Total polychlorinated biphenyls.

AR300474

5.6.3.2 Groundwater Use

Individuals using contaminated groundwater as a tap water source may be exposed to chemicals in the groundwater by direct ingestion, by inhalation of contaminants that have volatilized from the tap water during use, or by direct contact and dermal absorption of contaminants. Inhalation exposures can result from tap water use for showers, washing machines, dish washers, and kitchen use (i.e., cooking) and cleaning, and these exposure sources are selected for evaluation. Bathing was selected for the direct contact scenario because it is an activity that results in prolonged contact of the entire body surface with water. Other activities, such as hand washing dishes by hand, result in direct contact with tap water, but the duration of these activities and the amount of body surface area in contact with the water are believed to be less than that while bathing. Inhalation exposures while bathing also are considered.

The particular approaches used to quantify exposure under each of these pathways are discussed below. Potential risks associated with the use of residential well water are assessed under the current-use scenarios.

Ingestion of Groundwater

CDIs from groundwater ingestion are estimated, assuming a 70-kg individual consumes 2 liters of water each day for a lifetime (70 years). The CDIs and the potential carcinogenic and noncarcinogenic risks for the groundwater ingestion current-use pathway are presented in Table 5-19. The estimated, lifetime, upper-bound, excess cancer risk is 2×10^{-6} under the average case and 1×10^{-4} under the plausible maximum case. Ingestion of groundwater appears to present a low probability of adverse noncarcinogenic health effects under both the average and plausible maximum case, since the hazard index is less than one for both cases.

Inhalation of Contaminants Volatilized From Groundwater

In this section, the transfer of VOCs from various emission sources into the air and their subsequent inhalation is estimated.

As discussed above, exposure to volatile contaminants can result from household use of contaminated residential well water for showers, washing machines, dish washers, kitchen uses, and cleaning. Theoretical models are not available to calculate potential exposures associated with each of these sources. However, estimates of air concentrations of volatile organic compounds that might be expected while showering can be derived using the theoretical model of Foster and Chrostowski (1986, 1987; outlined in Appendix K). Estimates of air concentrations resulting from emissions from other sources can be calculated by adjusting the shower model for various source specific parameters.

TABLE 5-19
EXPOSURES AND RISKS ASSOCIATED WITH
INGESTION OF GROUNDWATER BY CURRENT RESIDENTS
CROYDON TCE SITE

Compound	POTENTIAL CARCINOGENIC EFFECTS							
	Concentration (µg/l)		Chronic Daily Intake (CDI) (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk		
	Geometric Mean	Maximum	Average	Plausible Maximum		Average	Plausible Maximum	
chloroform	0.081	1.2	2.31E-06	3.43E-05	8.10E-02	6.9E-07	2.8E-06	
1,1-dichloroethane	0.044	2.97	1.26E-06	8.48E-05	9.10E-02	1.1E-07	7.7E-06	
1,1-dichloroethene	0.077	5.12	2.20E-06	1.46E-04	6.00E-01	1.3E-06	8.8E-05	
tetrachloroethene	0.069	4.30	1.97E-06	1.23E-04	5.10E-02	1.0E-07	6.3E-06	
trichloroethene	0.74	97	2.11E-05	2.77E-03	1.10E-02	2.3E-07	3.0E-05	
TOTAL	--	--	--	--	--	2E-06	1E-04	

AR300476

TABLE 5-19
EXPOSURES AND RISKS ASSOCIATED WITH
INGESTION OF GROUNDWATER BY CURRENT RESIDENTS
CROYDON TCE SITE
PAGE TWO

Compound	NONCARCINOGENIC EFFECTS (a)						
	Concentration (µg/l)		Chronic Daily Intake (CDI) (mg/kg/day)		Reference Dose (RfD) (mg/kg/day)	Ratio of CDI:RfD	
	Geometric Mean	Maximum	Average	Plausible Maximum		Average	Plausible Maximum
chloroform	0.081	1.2	2.31E-06	3.43E-05	1.00E-02	2.3E-04	3.4E-03
1,1-dichloroethane	0.044	2.968	1.26E-06	8.48E-05	1.20E-01	1.0E-05	7.1E-04
1,1-dichloroethene	0.077	5.122	2.20E-06	1.46E-04	9.00E-03	2.4E-04	1.6E-02
tetrachloroethene	0.069	4.302	1.97E-06	1.23E-04	2.00E-02	9.9E-05	6.1E-03
1,1,1-trichloroethane	0.14	75.071	4.00E-06	2.14E-03	9.00E-02	4.4E-05	2.4E-02
HAZARD INDEX	--	--	--	--	--	<1 (6E-04)	<1 (0.05)

(a) Noncarcinogens and potential carcinogens with RfDs were evaluated for noncarcinogenic risk.

AR300477

The shower model of Foster and Chrostowski (1986, 1987) estimates the transfer of VOCs from shower droplets to air and their subsequent inhalation. The duration of exposure while showering is assumed to be 15 minutes per day and the total duration of exposure (i.e., including time spent in the shower room after showering) is assumed to be 20 minutes. It is conservatively assumed that once inhaled, the volatilized organic compounds are all absorbed across the lung lining with 75 percent efficiency. Although lower absorption efficiencies have been reported by some investigators, no estimated pulmonary absorption efficiencies greater than 75 percent have been reported in the available literature. This model does not estimate the potential dermal absorption of contaminants while showering. However, due to the nature of showering, dermal absorption is likely to result in minimal incremental exposure.

A sensitivity analysis of the shower model (Foster and Chrostowski 1986, 1987) indicated that the total estimated exposure for an individual, assumed to shower once per day is most sensitive to changes in tap water concentration, sensitivity increases by 1 percent for each 1 percent increase in concentration. Estimated exposures are somewhat less sensitive to other model input variables, changing by approximately 0.5 percent for each 1 percent change in the magnitude of the model input variables. Under the assumptions made in this report, the model employed predicts that approximately 25 percent of a volatile organic compound in shower water transfers to shower air. Given the uncertainties associated with selection of model input variables, exposure estimates derived from the shower room air model should be viewed as order-of-magnitude, relative estimates rather than absolute values.

Based on this exposure model, potential inhalation exposures to the groundwater contaminants that could volatilize during showering were estimated. The model yields estimates of the intake level (in mg/kg/day). Estimated intakes while showering associated with use of residential well water are presented in Table 5-20 for the average and plausible maximum cases.

The shower model incorporates an indoor air model to calculate the air concentration in the shower room associated with the volatilized organic chemicals. The indoor air model is a one compartment model which assumes instantaneous mixing in the room air and no chemical decay of the volatilized organic chemicals once they have been released into the indoor air. It is also assumed that the initial air concentration of volatile organic chemicals in the shower room, before the shower is turned on, is zero (i.e., there are no other sources of volatile organic chemicals contributing to the indoor air pollutant levels). These assumptions were also used when calculating the exposures associated with the other household emission sources of volatile organic chemicals from indoor use of contaminated groundwater.

TABLE 5-20

CDIs ASSOCIATED WITH INHALATION OF VOLATILE ORGANIC CHEMICALS
RELEASED FROM GROUNDWATER AT THE CROYDON TCE SITE
CURRENT-USE SCENARIO
(CDIs Listed in mg/kg/day)

Chemical	Concentration (ug/l)		Shower		Toilet		Laundry		Dishwasher		Kitchen		Cleaning	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum
chloroform	0.081	1.2	2.06E-04	3.05E-05	2.01E-08	2.98E-07	1.74E-07	2.58E-06	8.16E-08	8.15E-07	1.31E-07	1.31E-06	3.76E-08	3.76E-07
1,1-dichloroethane	0.044	2.968	1.22E-06	8.21E-05	1.19E-08	8.02E-07	1.03E-07	6.95E-06	3.26E-08	2.20E-06	5.26E-08	3.54E-06	1.50E-08	1.01E-06
1,1-dichloroethene	0.077	5.122	2.21E-06	1.47E-04	2.16E-08	1.44E-06	1.07E-07	1.24E-05	5.91E-08	3.93E-06	9.53E-06	6.34E-06	2.72E-08	1.01E-06
tetrachloroethene	0.069	4.302	1.60E-06	1.00E-04	1.57E-08	9.77E-07	1.36E-07	8.47E-06	4.28E-08	2.67E-06	6.91E-08	4.31E-06	1.90E-08	1.23E-06
1,1,1-trichloro- ethane	0.14	75.071	1.6E-07	1.90E-03	3.46E-08	1.86E-05	3.01E-07	1.61E-04	9.78E-08	5.08E-05	1.58E-07	8.19E-05	4.36E-08	2.34E-05
trichloroethene	0.74	97	1.85E-05	2.44E-03	1.82E-07	2.38E-05	1.58E-06	2.07E-04	9.78E-08	6.53E-05	8.03E-07	1.05E-04	2.29E-07	3.01E-05

AR300479

Estimated intakes associated with other household emission sources also are presented in Table 5-20. These values were derived by adjusting the shower model to reflect source-specific variations in the following parameters:

- The total time a particular source would be emitting VOCs.
- The total time of exposure to emissions from a given source.
- The volume of air in the room in which the source was located.
- The number of air changes in the room in which the source was located.

Source-specific CDIs derived from the shower model after these adjustments were made were further adjusted to reflect the expected frequency of exposure relative to the daily shower exposure, and the emission source efficiency relative to the shower emission source efficiency as reported by (Prichard and Gessell 1981). All the factors used to adjust the shower model output are listed in Table 5-21.

The potential carcinogenic and noncarcinogenic risks associated with inhalation exposures from the household emission sources are presented in Table 5-22. The estimated lifetime upper bound excess cancer risk is 4×10^{-6} under the average case and 2×10^{-4} under the plausible maximum case. Inhalation exposures to noncarcinogens appear to present little risk as the individual CDI:RfD ratios and the hazard index under the average and plausible maximum case are less than one.

Exposures to Groundwater Contaminants while Bathing

Individuals who bathe may be exposed to volatile organic chemicals of potential concern via dermal absorption from contaminated bath water and inhalation of volatilized chemicals. Estimates of exposure from dermal absorption are based on the work of Wester et al. (1987). Estimates of inhalation exposures while bathing are made using the adjusted shower exposure model of Foster and Chrostowski (1986, 1987), as described above.

Wester et al. (1987) measured the amounts of benzene transferred into human skin (5.7 cm^2) from a dilute ($21.7 \text{ } \mu\text{g/ml}$) solution in water (1.5 ml) over a 30-minute period. The amount of benzene which could be transferred into the skin during a bath was conservatively assumed to be the sum of the amounts of benzene absorbed through the various layers of the skin (epidermis, dermis, and stratum corneum). This sum, which was adjusted for the total skin surface area expected to be exposed during a bath [assumed to be approximately 80 percent of the $19,400 \text{ cm}^2$ adult body surface area (EPA 1985e)] amounted to 0.15 percent of the dose to which the skin was exposed.

AR300480

TABLE 5-21

PARAMETERS USED TO CALCULATE INDOOR AIR EXPOSURE
FROM VOLATILE ORGANIC CHEMICALS

Emission Source	Duration of VOC Emissions (Hours)	Duration of Exposure (Hours)	Room Volume for Each Source (m3)	Room Air Exchanges per Hour (hr-1)	Number of Exposures per Week	Ratio of Source Efficiency to Shower Efficiency (e)
Shower	0.25	0.33	6	0.5 (c)	7	1.0
Tub Baths (a)	0.25	0.33	6	0.5	7	0.75
Toilet	1.67E-02	3.33E-02	6	0.5	7	1.16
Laundry	1.0	12.0	255 (b)	2.0 (d)	2	1.24
Dishwasher	0.5	12.0	255	2.0	3	0.52
Kitchen Use	2.0	12.0	255	2.0	7	0.09
Cleaning	2.0	12.0	255	2.0	2	0.09

a = Addressed in following section on exposure associated with tub baths.

b = Based on room dimensions of 30' x 30' x 10'.

c = Based on the number of air exchanges per hour for a room with no windows or exterior doors (Wadden and Scheff, 1983).

d = Based on the number of air exchanges per hour for a room with windows or exterior doors on three sides (Wadden and Scheff, 1983).

e = Obtained from data given by Prichard and Gesell (1981). Efficiency is the product of the transfer efficiency and the daily consumption of water for each emission source as given in Prichard and Gesell (1981).

AR300481

TABLE 5-22

**EXPOSURES AND RISKS ASSOCIATED WITH INHALATION OF
VOLATILE ORGANIC CHEMICALS RELEASED FROM GROUNDWATER
CROYDON TCE SITE**

Compound	POTENTIAL CARCINOGENIC EFFECTS				
	Chronic Daily Intake (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Average	Plausible Maximum		Average	Plausible Maximum
chloroform	2.42E-06	3.59E-05	8.10E-02	3E-07	3E-06
1,1-dichloroethane	1.44E-06	9.66E-05	9.00E-02	1E-07	9E-06
1,1-dichloroethene	2.60E-06	1.70E-04	1.20E+00	3E-06	2E-04
tetrachloroethene	1.89E-06	1.20E-04	3.30E-02	5E-08	4E-06
trichloroethene	1.85E-06	2.87E-03	4.60E-03	1E-08	1E-05
TOTAL				4E-06	2E-04

Compound	NONCARCINOGENIC EFFECTS				
	Chronic Daily Intake (mg/kg/day)		Reference Dose (RfD) (mg/kg/day)	Ratio of CDI:RfD	
	Average	Plausible Maximum		Average	Plausible Maximum
chloroform	2.42E-06	3.59E-05	1.00E-02	4E-04	3E-03
1,1-dichloroethane	1.44E-06	9.66E-05	1.20E-01	1E-05	8E-04
1,1-dichloroethene	2.60E-06	1.73E-04	9.00E-03	3E-04	2E-04
tetrachloroethene	1.84E-06	1.18E-04	2.00E-02	8E-05	6E-03
1,1,1-trichloroethane	1.88E-06	2.23E-03	9.00E-02	3E-05	2E-02
TOTAL				<1(8E-4)	<1(0.03)

AR300482

Because dermal absorption of organic chemicals from dilute solution is, to a first approximation, proportional to the lipophilicity of the chemicals (Foster and Chrostowski 1986), doses for each organic chemical were derived based on (1) the ratio of the aqueous concentration of each chemical of concern in the bath water to the aqueous concentration of benzene used in the Wester et al. (1987) study, and (2) the ratio of the octanol-water partition coefficient (K_{ow}) of benzene (132) to that of each organic chemical of concern. Based on these ratios, masses of each chemical of concern transferred into the skin during a 30-minute bath were estimated. Chronic daily intakes (CDIs) were then calculated by assuming that an average 70-kg adult takes 1 bath per day for a 70-year lifetime.

Table 5-23 presents the estimated CDIs from dermal absorption along with the estimated inhalation CDIs calculated from the adjusted shower model of Foster and Chrostowski (1986,1987) using the parameters listed in Table 5-21. The potential carcinogenic and noncarcinogenic risks associated with the combined exposure also are presented in this table. The estimated, lifetime, upper-bound, excess cancer risk is 5×10^{-6} under the average case and 4×10^{-4} under the plausible maximum case. Inhalation exposures to noncarcinogens appears to present little risk as the individual CDI:RfD ratios and the hazard index under the average and plausible maximum case are less than one.

5.6.3.3 Direct Contact with Contaminated Sediments

As discussed previously, individuals boating in Neshaminy Creek may be exposed to PAHs in the sediments while wading in the water during boat docking or launching. Additionally, children playing in the Hog Run Creek may be exposed to sediment PAHs while wading or playing. The approach to calculating CDIs for these exposure pathways is identical to those used for the direct contact with soil scenarios discussed previously, except that only dermal contact and absorption is assessed. Incidental ingestion of sediments is considered unlikely because sediments are expected to be in contact only with the feet and are likely to be washed off in the water before reaching the hands or mouth.

Direct Contact with Neshaminy Creek Sediments by Adults

Under this pathway, adults are assumed to contact sediments once (average case) or twice (plausible maximum) a week for 4 months each year. Average-case exposure is assumed to occur for 5 years and plausible, maximum-case exposure for 20 years. Sediment contact rates of 0.52 g/event and 1.57 g/event are used for the average and plausible maximum cases, respectively. These values were derived using soil contact rates of 0.5 mg/cm² and 1.5 mg/cm² (Schaum 1984) and an assumed exposed surface area of 1,047 cm², representing the average surface area

AR300483

TABLE 5-23
EXPOSURES AND RISKS ASSOCIATED WITH BATHING WITH GROUNDWATER
CROYDON TCE SITE

A. POTENTIAL CARCINOGENIC EFFECTS

Compound	Concentration (µg/L)		Quantity of Chemical Absorbed (mg/kg/day)		Quantity of Chemical Absorbed Via Inhalation (mg/kg/day)		Oral Potency Factor (mg/kg/day) ⁻¹	Inhalation Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum			Average	Plausible Maximum
Chloroform	0.081	1.2	5.01E-09	7.21E-08	3.61E-06	5.35E-05	8.10E-02	8.10E-02	2.9E-07	4.3E-06
1,1-Dichloroethane	0.044	2.968	1.80E-09	1.21E-07	2.14E-06	1.44E-04	9.10E-02	----	2.0E-07	1.3E-05
1,1-Dichloroethene	0.077	5.122	6.89E-09	4.58E-07	3.88E-06	2.58E-04	6.00E-01	1.20E+00	4.7E-06	3.1E-04
Tetrachloroethane	0.069	4.302	1.82E-08	1.14E-06	2.81E-06	1.76E-04	5.10E-02	3.30E-02	9.4E-08	5.8E-06
Trichloroethene	0.74	97	1.18E-07	1.54E-05	3.27E-06	4.28E-03	1.10E-02	4.60E-03	1.5E-07	2.0E-05
TOTAL	--	--	--	--	--	--	--	--	5E-06	4E-04

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TABLE 5-23
EXPOSURES AND RISKS ASSOCIATED WITH BATHING WITH GROUNDWATER
CROYDON TCE SITE
PAGE TWO

B. NONCARCINOGENIC EFFECTS(a)

Compound	Concentration (µg/L)		Quantity of Chemical Dermal Absorbed CDI (mg/kg/day)		Quantity of Chemical Absorbed Via Inhalation (mg/kg/day)		Oral Reference Dose (RfD) (mg/kg/day)	Inhalation Reference Dose (RfD) (mg/kg/day)	Ratio of CDI:RfD	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum			Average	Plausible Maximum
Chloroform	0.081	1.2	5.01E-09	7.43E-08	3.61E-07	5.35E-05	1.00E-02	----	3.7E-05	5.4E-03
1,1-Dichloroethane	0.044	2.968	1.80E-09	1.21E-07	2.14E-06	1.44E-04	1.20E-01	1.30E-01	1.6E-05	1.1E-03
1,1-Dichloroethene	0.077	5.122	6.89E-09	4.58E-07	3.88E-06	2.58E-04	9.00E-03	----	4.3E-04	2.9E-02
Tetrachloroethene	0.069	4.302	1.82E-08	1.14E-06	2.81E-06	1.76E-04	2.00E-02	----	1.4E-04	8.8E-03
1,1,1-Trichloroethane	0.14	75.071	2.94E-08	1.57E-05	6.22E-06	3.33E-03	9.00E-02	3.10E+00	2.3E-06	1.3E-03
HAZARD INDEX	--	--	--	--	--	--	--	--	<1(0.001)	<1(0.04)

(a) Noncarcinogens and potential carcinogens with RfDs were evaluated for noncarcinogenic risk.

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of the feet of adult males and females (EPA 1985a). The dermal absorption factor for PAHs is identical to that in the soil direct-contact scenario.

The CDIs and associated risks calculated using these assumptions are presented in Table 5-24. The lifetime, upper-bound, excess cancer risk resulting from exposure to PAHs in the sediment is 3×10^{-8} under the average case and 3×10^{-6} under the plausible maximum case.

Direct Contact with Hog Run Creek Sediments by Children

Under this pathway, children between 6 and 10 years of age and weighing 27 kg are assumed to wade in Hog Run Creek once a week (average case) or twice a week (plausible maximum case) for four months each year, for a total of 16 or 32 exposure events each year. The total years of exposure are assumed to be five. Sediment contact rates of 0.3 g/event and 1.0 g/event are used for the average and plausible maximum cases, respectively, derived using the soil contact rates of Schaum (1984) presented above and an assumed exposed surface area of 693 cm², representing the average surface area of the feet of male and female children between 6 and 10 years of age (EPA 1985e). The dermal absorption factor for PAHs is identical to that used in the sediment contact scenario above.

Table 5-25 presents the CDIs and risks calculated using these assumptions. The lifetime upper-bound excess cancer risk resulting from exposure of children to PAHs in the sediments of Hog Run Creek is 2×10^{-8} under the average case and 4×10^{-7} under the plausible maximum case.

5.6.4 Estimate of Exposure and Assessment of Risk Under Future Conditions

In this section, potential exposures and risks under future use conditions are estimated. In the absence of future remedial actions and institutional actions limiting access to the site and surrounding area, the routes of exposure quantified for current use conditions also would apply in the future. In addition, the site may be developed in the future as a residential area, resulting in potential exposure of residents to contaminants in soils.

The exposure and risk estimates in this section are based on the assumption that soil and sediment concentrations do not change over time, but that contaminant concentrations in residential wells will change because of contaminant migration and will be equal to the concentrations currently detected in the monitoring wells. Assuming exposure concentrations do not change in soil or sediment, current and future risks for soil and sediment exposures would be identical. Therefore, only risks associated with residential well water use in the future and future residential soil exposure will be evaluated in this section.

TABLE 5-24
EXPOSURES AND RISKS ASSOCIATED WITH CONTACT OF SEDIMENTS IN NESHAMINY CREEK BY ADULTS
CROYDON TCE SITE

Compound	Sediment Concentration (mg/kg)		Quantity of Chemical Dermal Absorbed (mg/kg/d)		Chronic Daily Intake, Based on a Lifetime exposure (mg/kg/d)		Potency Factor (mg/kg/d) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum		Average	Plausible Maximum
CPAHs (a)	2.27E+00	1.02E+01	2.66E-09	2.87E-07	2.66E-09	2.87E-07	1.15E+01	3.1E-08	3.3E-06
TOTAL								3E-08	3E-06

(a) Carcinogenic polynuclear aromatic hydrocarbons.

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TABLE 5-25
EXPOSURES AND RISKS ASSOCIATED WITH CONTACT OF SEDIMENTS
IN HOG RUN CREEK BY CHILDREN
CROYDON TCE SITE

Compound	Sediment Concentration (mg/kg)		Quantity of Chemical Dermalily Absorbed (mg/kg/day)		Chronic Daily Intake, Based on a Lifetime Exposure (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum		Average	Plausible Maximum
PAHs(a)	1.05E+00	2.56E+00	2.12E-09	3.09E-08	2.12E-09	3.09E-08	1.15E+01	2.4E-08	3.6E-07
TOTAL								2E-08	4E-07

(a)Carcinogenic polynuclear aromatic hydrocarbons.

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5.6.4.1 Groundwater Use

Potential exposure pathways associated with groundwater use under future conditions are identical to those under current use: groundwater ingestion, inhalation of contaminants volatilized from groundwater during household use, and dermal absorption and inhalation of contaminants while bathing. The approaches used to quantify exposure under future and current use conditions also are identical and, therefore, will not be repeated here. However, for future use conditions, contaminant concentrations currently detected in the monitoring wells are used as exposure point concentrations rather than the residential wells used under current use conditions.

Chronic daily intakes (CDIs) and risks associated with exposure to contaminated groundwater in the future are presented in Tables 5-26 through 5-29. Because of the differences in concentrations between the residential wells and monitoring wells, the CDIs and associated risks are not the same for the current and future use conditions.

For the groundwater ingestion pathway, the estimated, lifetime, upper-bound, excess cancer risk is 7×10^{-5} under the average case and 2×10^{-3} under the plausible maximum case. The individual CDI:RfD ratios and the hazard index are less than one under both the average and plausible maximum case. It should be noted, however, that where exposure to noncarcinogens is assessed for young children weighing 10 kg and ingesting 1 liter of water each day, the hazard index exceeds 1 under the plausible maximum case. Grouping the noncarcinogens based on target organ toxicity also results in a hazard index greater than 1 for exposure to the liver toxicants.

For the inhalation pathway, the estimated lifetime upper bound excess cancer risk is 7×10^{-6} under the average case and 3×10^{-3} under the plausible maximum case. The individual CDI:RfD ratios and the hazard index are less than one under both the average and plausible maximum case.

For bathing exposures, the estimated, lifetime, upper-bound excess cancer risk is 2×10^{-5} for the average case and 5×10^{-3} for the plausible maximum case. The individual CDI:RfD ratios and the hazard index are less than one under the average case. The hazard index is greater than one under the plausible maximum case.

5.6.4.2 Direct Contact with Contaminated Soil by Future Residents

If the ballfield area of the Croydon TCE Site is developed in the future as a residential area, individuals living in the area may be exposed to chemicals of potential concern in the soil.

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TABLE 5-26
EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
CROYDON TCE SITE

A. POTENTIAL CARCINOGENIC EFFECTS

Compound	Concentration (µg/l)		Chronic Daily Intake (mg/kg/d)		Potency Factor (mg/kg/d) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum		Average	Plausible Maximum
Chloroform	0.15	8.9	4.29E-06	2.54E-04	8.10E-02	3.5E-07	2.1E-05
1,1-Dichloroethane	0.07	3	2.00E-06	8.57E-05	9.10E-02	1.8E-07	7.8E-06
1,1-Dichloroethene	0.16	75	4.57E-06	2.14E-03	6.00E-01	2.7E-06	1.3E-03
4,4'-DDT	NA	0.77	- -	2.2E-05	3.40E-01	- -	7.5E-06
Dieldrin	0.08	0.3	2.29E-06	8.57E-06	3.00E+01	6.9E-05	2.6E-04
Tetrachloroethane	0.09	4.1	2.57E-06	1.17E-04	5.10E-02	1.3E-07	6.0E-06
Trichloroethene	1.1	420	3.14E-05	1.20E-02	1.10E-02	3.5E-07	1.3E-04
TOTAL	--	--	--	--	--	7E-05	2E-03

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TABLE 5-26
EXPOSURES AND RISKS ASSOCIATED WITH INGESTION OF GROUNDWATER
CROYDON TCE SITE
PAGE TWO

B. NONCARCINOGENIC EFFECTS (a)

Compound	Concentration (µg/l)		Chronic Daily Intake (CDI) (mg/kg/d)		Reference Dose (RfD) (mg/kg/d)	Ration of CDI:RfD	
	Geometric Mean	Maximum	Average	Plausible Maximum		Average	Plausible Maximum
Chloroform	0.15	8.9	4.29E-06	2.54E-04	1.00E-02	4.3E-04	2.5E-02
1,1-Dichloroethane	0.07	3	2.00E-06	8.57E-05	1.20E-01	1.7E-05	7.1E-04
1,1-Dichloroethene	0.16	75	4.57E-06	2.14E-03	9.00E-03	5.1E-04	2.4E-01
4,4'-DDT	NA	0.77	- -	2.20E-05	5.00E-04	- -	4.4E-02
Tetrachloroethene	0.09	4.1	2.57E-06	1.17E-04	2.00E-02	1.3E-04	5.9E-03
1,1,1-Trichloroethane	0.44	160	1.31E-05	4.57E-03	9.00E-02	1.5E-04	5.1E-02
HAZARD INDEX	--	--	--	--	--	<1(0.001)	<1(0.3)

(a) Noncarcinogens and potential carcinogens with RfDs were evaluated for noncarcinogenic risk.
NA Not Applicable. Geometric mean is not calculated with only one positive detection.

AR300491

TABLE 5-27

CDIs ASSOCIATED WITH INHALATION OF VOLATILE ORGANIC CHEMICALS RELEASED FROM GROUNDWATER
CROYDON TCE SITE
FUTURE-USE SCENARIO
All Concentrations in µg/Liter

Chemical	Concentration		Shower		Toilet		Laundry		Dishwasher		Kitchen		Cleaning	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum
Chloroform	0.15	8.9	3.81E-06	2.26E-04	3.72E-08	2.21E-06	3.23E-07	1.91E-05	1.02E-07	6.04E-06	1.64E-07	9.74E-06	4.69E-08	2.78E-06
1,1,1-Trichloroethane	NA	0.77	-	9.36E-06	-	9.12E-08	-	7.92E-07	-	2.50E-08	-	4.03E-07	-	1.15E-08
1,1-Dichloroethane	0.07	3	1.94E-06	8.30E-05	1.89E-08	8.11E-07	1.64E-07	7.03E-06	5.19E-08	2.22E-06	8.36E-08	3.56E-06	2.39E-08	1.02E-06
1,1-Dichloroethene	0.16	75	4.60E-6	2.15E-03	4.49E-08	2.10E-05	3.89E-07	1.82E-04	1.23E-07	5.75E-05	1.98E-07	9.27E-05	5.67E-08	2.63E-05
Bleedrin	0.08	0.3	2.84E-09	1.06E-08	2.77E-11	1.84E-10	2.67E-10	8.98E-10	7.56E-11	2.83E-10	1.22E-10	4.57E-10	3.48E-11	1.31E-10
Tetrachloroethane	0.094	4.1	2.19E-06	9.54E-05	2.14E-08	9.32E-07	1.85E-07	8.08E-06	5.86E-08	2.55E-06	9.44E-08	4.11E-06	2.70E-08	1.17E-06
1,1,1-Trichloroethane	0.44	160	1.12E-05	4.06E-03	1.09E-07	3.97E-05	9.48E-07	3.44E-04	3.00E-07	1.09E-04	4.83E-07	1.75E-04	1.38E-07	5.80E-05
Trichloroethene	1.1	420	2.77E-05	1.06E-02	2.71E-07	1.04E-04	2.35E-06	8.98E-04	7.41E-07	2.83E-04	1.19E-06	4.57E-04	3.41E-07	1.31E-04

NA = Not applicable. Geometric mean is not calculated with one positive detection.

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TABLE 5-28

**EXPOSURES AND RISKS ASSOCIATED WITH INHALATION OF VOLATILE
ORGANIC CHEMICALS RELEASED FROM GROUNDWATER
AT THE CROYDON TCE SITE
FUTURE-USE SCENARIO**

POTENTIAL CARCINOGENIC EFFECTS

Chemical	Chronic Daily Intake (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Average	Plausible Maximum		Average	Plausible Maximum
Chloroform	4.48E-06	2.66E-04	8.10E-02	4E-07	2E-05
4,4'-DDT	NA	1.10E-06	3.40E-01	--	1E-06
1,1-Dichloroethane	2.28E-06	9.77E-05	9.00E-02	2E-07	9E-06
1,1-Dichloroethene	5.41E-06	2.53E-03	1.20E+00	6E-06	3E-03
Dieldrin	3.29E-09	1.25E-08	3.00E+01	1E-07	4E-07
Tetrachloroethene	2.58E-06	1.12E-04	3.30E-02	9E-08	4E-06
Trichloroethene	3.26E-05	1.25E-02	4.60E-03	1E-07	6E-05
TOTAL				7E-06	3E-03

NONCARCINOGENIC EFFECTS

Chemical	Chronic Daily Intake (mg/kg/day)		Reference Dose (RfD) (mg/kg/day)	Ratio of CDI:RfD	
	Average	Plausible Maximum		Average	Plausible Maximum
Chloroform	4.4E-06	2.66E-04	1.00E-02	4E-04	3E-02
1,1-Dichloroethane	2.28E-06	9.77E-05	1.20E-01	2E-05	8E-04
1,1-Dichloroethene	5.41E-06	2.53E-03	9.00E-03	6E-04	3E-01
4,4'-DDT	NA	1.10E-05	5.00E-04	--	2E-02
Tetrachloroethene	2.58E-06	1.12E-04	2.00E-02	1E-04	6E-03
1,1,1-Trichloro- ethane	2.80E-05	4.78E-03	9.00E-02	3E-05	5E-02
TOTAL				<1 (0.001)	<1 (0.4)

NA Not applicable. Geometric mean not calculated with only one positive detection.

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TABLE 5-29
EXPOSURES AND RISKS ASSOCIATED WITH BATHING WITH GROUNDWATER - FUTURE USE
CROYDON TCE SITE

A. POTENTIAL CARCINOGENIC EFFECTS

Compound	Concentration (µg/L)		Quantity of Chemical Dermal Absorbed CDI (mg/kg/day)		Quantity of Chemical Absorbed Via Inhalation (mg/kg/day)		Oral Potency Factor (mg/kg/day) ⁻¹	Inhalation Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum			Average	Plausible Maximum
Chloroform	0.15	8.9	9.28E-09	5.51E-07	6.69E-06	3.97E-04	8.10E-02	8.10E-02	5.4E-07	3.2E-05
4,4'-DDT	NA	0.77	NC	2.05E-04	NC	1.64E-05	3.40E-01	---	NC	2.7E-04
1,1-Dichloroethane	0.07	3	2.66E-09	1.23E-07	3.40E-06	1.46E-04	9.10E-02	---	3.1E-07	1.3E-05
1,1-Dichloroethene	0.16	75	1.43E-08	6.71E-06	8.07E-06	3.77E-03	6.00E-01	1.20E+00	9.7E-06	4.5E-03
Dieldrin	0.08	0.3	1.68E-07	6.29E-07	4.98E-09	1.86E-08	3.00+01	---	5.2E-06	1.9E-05
Tetrachloroethane	0.094	4.1	2.48E-08	1.08E-06	3.84E-06	1.67E-04	5.10E-02	3.30E-02	1.3E-07	5.6E-06
Trichloroethene	1.1	420	1.75E-07	6.68E-05	4.86E-05	1.86E-02	1.10E-02	4.60E-03	2.4E-07	8.6E-05
TOTAL	---	---	---	---	---	---	---	---	2E-05	5E-03

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TABLE 5-29
EXPOSURES AND RISKS ASSOCIATED WITH BATHING WITH GROUNDWATER - FUTURE USE
CROYDON TCE SITE
PAGE TWO

B. NONCARCINOGENIC EFFECTS (a)

Compound	Concentration (ug/L)		Quantity of Chemical Dermally Absorbed CDI (mg/kg/day)		Quantity of Chemical Absorbed Via Inhalation (mg/kg/day)		Oral Reference Dose (RfD) (mg/kg/day)	Inhalation Reference Dose (RfD) (mg/kg/day)	Ratio of CDI:RfD	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum			Average	Plausible Maximum
Chloroform	0.15	8.9	9.28E-09	5.51E-07	6.69E-06	3.97E-04	1.00E-02	---	6.7E-04	4.0E-02
4,4'-DDT	NA	0.77	- -	7.91E-04	- -	1.64E-05	5.00E-04	---	- -	1.6E-00
1,1-Dichloroethane	0.07	3	2.86E-09	1.23E-07	3.40E-06	1.46E-04	1.20E-01	1.30E-01	2.6E-05	1.1E-03
1,1-Dichloroethene	0.16	75	1.43E-08	6.71E-06	8.07E-06	3.77E-03	9.00E-03	---	9.0E-04	4.2E-01
Tetrachloroethene	0.094	4.1	2.48E-08	1.08E-06	3.84E-06	1.67E-04	2.00E-02	---	1.9E-04	8.4E-03
1,1,1-Trichloroethene	0.44	160	9.23E-08	3.35E-05	1.97E-05	7.13E-03	9.00E-02	3.10E+00	7.4E-06	2.7E-03
HAZARD INDEX	---	---	---	---	---	---	---	---	<1(0.002)	>1(2)

(a) Noncarcinogens and potential carcinogens with RfDs were evaluated for noncarcinogenic risk.
NA Not Applicable. Geometric mean is not calculated with only one positive detection.

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To assess potential exposures and risks to future residents, the soil data presented in Table 5-4 are used. Lifetime exposure assumptions are identical to those used previously to assess current lifetime residential exposure. Chronic daily intake (CDI) estimates for incidental soil ingestion and dermal absorption of chemical contaminants are calculated using procedures similar to those used for the current-use direct contact scenario. Table 5-30 presents the average and plausible maximum CDIs, as well as the potential carcinogenic risks associated with future residential exposures. The estimated lifetime, upper-bound, excess cancer risk is 6×10^{-6} under the average case and 9×10^{-4} under the plausible maximum case.

5.6.5 Multimedia Exposures

Exposure via one of the pathways discussed above for either the current- or future-use scenarios does not preclude exposures via other pathways. For example, current residents who play ball and own a boat moored on Neshaminy Creek may be exposed to contaminated soil and sediments and contaminated tap water. Future site residents could also be exposed to contaminated sediments and groundwater. However, exposure by one route generally dominates the exposure and risk calculations, and adding exposures from other routes is unlikely to have a substantial effect on risks. For example, under the average current-use scenario, the upper-bound, excess, lifetime cancer risk associated with direct contact by ball players with surface soil is 6×10^{-8} . The upper bound, lifetime cancer risk associated with the inhalation of vapors released while using water in the home is 4×10^{-6} , and that associated with the ingestion of groundwater is 2×10^{-6} . The sum of these three values is equal to the risk value associated with groundwater related exposures. Therefore, in this situation, the quantitative risk is determined by only one medium of exposure, although several pathways exist.

5.7 ENVIRONMENTAL ASSESSMENT

In this section the potential impacts on nonhuman receptors associated with the chemicals of potential concern at the Croydon TCE Site are evaluated. Below, plants and animals potentially exposed to the chemicals of potential concern are identified, then brief summaries of available environmental toxicity data and estimates of exposure of potential receptors are presented. Finally estimates of risks are made.

5.7.1 Potential Receptors

Plants and animals may be exposed to chemicals of potential concern in the surface water, sediments, and soils of the Croydon TCE Site. Surface water and sediment contamination has been identified in Neshaminy Creek, Hog Run Creek, and a pond located behind the VFW post. Soil contamination has been identified at the three onsite soil sampling locations.

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TABLE 5-30

EXPOSURES AND RISKS ASSOCIATED WITH CONTACT OF SOILS BY FUTURE RESIDENTS AT THE CROYDON TCE SITE

A. POTENTIAL CARCINOGENIC EFFECTS

Compound	Soil Concentration (mg/l)		Quantity of Chemical Ingested and Absorbed via Ingestion (mg/kg/day)		Quantity of Chemical Dermalily Absorbed (mg/kg/day)		Chronic Daily Intake, based on a Lifetime Exposure (mg/kg/day)		Potency Factor (mg/kg/day) ⁻¹	Lifetime Upper Bound Excess Cancer Risk	
	Geometric Mean	Maximum	Average	Plausible Maximum	Average	Plausible Maximum	Average	Plausible Maximum		Average	Plausible Maximum
CPAHs (a)	2.30E+00	3.11E+01	8.10E-08	1.48E-05	3.95E-07	6.13E-07	4.76E-07	7.62E-05	1.15E+01	5.5E-06	8.8E-04
PCBs (b)	1.20E-01	5.90E-01	4.23E-09	2.81E-07	2.89E-08	1.63E-06	3.31E-08	1.91E-06	7.70E+00	2.5E-07	1.5E-05
TOTAL	---	---	---	---	---	---	---	---	---	6E-06	9E-04

(a) Carcinogenic polynuclear aromatic hydrocarbons.

(b) Total polychlorinated biphenyls.

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Both Neshaminy Creek and Hog Run Creek are tidal, freshwater tributaries of the Delaware River. The areas provide a diversity of habitats (e.g., riffles and pools, muddy and rocky substrate) and therefore probably support a variety of aquatic life. Potential receptors include numerous freshwater plant species, fish, insects, mollusks, and other invertebrate species, as well as reptiles and amphibians. Similar types of species can be expected to occur in the onsite pond, although habitat diversity, and, therefore, species diversity, is probably less than in the tidal creeks.

Aquatic species in the Delaware River are potential additional receptors of contaminants from Neshaminy and Hog Run Creeks. However, potential impacts on these species are likely to be negligible because the concentrations of contaminants reaching the river will be reduced significantly by dispersion and dilution within the river.

Terrestrial species are not likely to be receptors at the site. Because of industrial and residential development little wildlife is found in the areas of soil contamination. Terrestrial species using the wetland and wooded areas adjacent to Neshaminy and Hog Run Creeks may potentially be exposed to chemicals of potential concern detected in the surface water and sediments of these areas; however, none of the chemicals detected in the creeks bioaccumulate, and, therefore, exposure to these chemicals via the food chain is not likely.

5.7.2 Aquatic Toxicity of the Chemicals of Potential Concern

1,1,1-Trichloroethane and trichloroethene were detected in Hog Run Creek and the onsite pond. In addition, PAHs were detected in the sediments from each of these areas, as well as in Neshaminy Creek.

Aquatic toxicity data on the surface water contaminants are limited almost exclusively to data on acute lethality of the compounds. In general, these compounds are acutely toxic only at very high concentrations. Alexander et al. (1978) reported a 96-hour median lethal concentration (LC₅₀) of 52,800 µg/liter for 1,1,1-trichloroethane. Acutely toxic concentrations of trichloroethene were similar with an LC₅₀ of 45,000 µg/liter reported (EPA 1987g). A freshwater chronic value of 21,900 µg/liter was reported for trichloroethene (EPA 1987g).

Data which relate sediment levels of PAHs to toxic effects in aquatic organisms are limited. Chapman et al. (1987) reported a range of sediment PAH concentrations believed to be associated with no or minimal adverse biological effects. The levels ranged from 2.0 mg/kg to 12.0 mg/kg and were based on laboratory and field data of toxic effects observed following exposure to PAHs in marine sediments. Similar data are not available for the effects of sediment PAHs in freshwater systems, and, therefore, the Chapman et al. (1987) values for marine systems

will be used to estimate potential adverse effects in the freshwater systems at the Croydon TCE site.

5.7.3 Exposure Concentrations

1,1,1-Trichloroethane and trichloroethene were detected in Hog Run Creek and the onsite pond at relatively low levels. The geometric mean and maximum concentrations of 1,1,1-trichloroethane in Hog Run Creek and pond were 0.10 and 1.8 µg/liter and 2.2 and 2.3 µg/liter, respectively. Trichloroethene was detected at geometric mean and maximum concentrations of 0.76 and 6.1 µg/liter in Hog Run Creek and 3.8 and 6.1 µg/liter in the pond.

PAHs were detected in the sediments of Hog Run Creek, Neshaminy Creek, and the onsite pond. The reported mean and maximum concentrations were as follows: 2.8 and 6.5 mg/kg in Hog Run Creek; 2.2 and 2.3 mg/kg in Neshaminy Creek; and, 6.9 and 9.4 mg/kg in the onsite pond.

5.7.4 Potential Risks to Aquatic Receptors

Potential risks to aquatic receptors are estimated by comparing the concentrations of these chemicals known to be toxic to aquatic life with the reported mean and maximum exposure concentrations detected at the site. Based on these comparisons, potential toxic effects of 1,1,1-trichloroethane and trichloroethene in Hog Run Creek and the onsite pond do not appear likely. The concentrations for these chemicals in surface water at the site are well below (7 to 8 orders of magnitude) those levels associated with aquatic toxicity. Toxic effects in sensitive species may occur at concentrations lower than those reported to be toxic to the tested laboratory species, but it is unlikely that any toxicity would occur at the low concentrations observed in Hog Run Creek or the onsite pond.

The sediment concentrations of PAHs in Hog Run Creek, Neshaminy Creek, and the onsite pond are within the range of sediment concentrations believed to be associated with no or minimal biological effects, as reported by Chapman et al. (1987). Therefore, the sediment PAH concentrations observed at the Croydon TCE site may not be adversely impacting aquatic life.

In summary, the observed surface water and sediment concentrations at the Croydon TCE site do not appear to be at levels that are toxic to aquatic life. This conclusion is based on the assumption that the available toxicity data adequately characterize potential toxicity for the species present at the site and that the available monitoring data adequately characterize exposure levels for the potentially affected populations. In addition, the toxicity of the chemicals was assumed to be additive; potentiating or synergistic effects of chemicals were assumed to be absent. Each of these assumptions contributes to uncertainty in the risk assessment, and therefore, absolute conclusions of no effect cannot be made.

5.8 UNCERTAINTIES IN RISK ASSESSMENT

The procedures and inputs used to assess risks in this evaluation, as in all such assessments, are subject to a wide variety of uncertainty. In general, the following are the main sources of uncertainty:

- Environmental chemistry sampling and analysis
- Environmental parameter measurement
- Fate and transport modeling
- Exposure parameter estimation
- Toxicological data

Uncertainty in environmental sampling arises in part from the potentially uneven distributions of chemicals in the media samples. Typically, this problem is encountered more frequently in soil than in water or air. The collection of grab samples allows an estimate of the variation in the chemical concentration in the area to be made. Only eight soil samples were collected at the Croydon TCE site. The use of these data to characterize exposure to soil at the site leads to uncertainty because of the small database available.

Error in environmental chemistry analysis can stem from several sources, including the errors inherent in the analytical methods, chain of custody problems, or the characteristics of the matrix being sampled. For this RI, the analytical methods chosen were all methods approved by EPA. Procedural or systematic error was minimized by subjecting the data to a strict laboratory quality control review and data validation process. Based on the data validation, some data were considered unusable and certain data were qualified. For example, during validation some of the samples were qualified as being estimated values. These concentrations were subsequently used to calculate geometric means and in some cases, were the maximum value detected. Hence, risks calculated using these results may be under- or overestimated, although given the generally conservative nature of the exposure scenarios assumed in this risk assessment, this is considered unlikely.

Another analytical problem potentially affecting the risk assessment involved the sample detection limits attained for the chemicals of concern at the Croydon TCE Site. Although certain chemicals were not detected in groundwater or soils and sediments at the Croydon TCE site, the sample detection limits may have been higher than either ARARs or levels indicative of significant risk. It is uncertain, therefore, whether these chemicals are present above or below a level of concern in these media at the Croydon TCE Site. If these chemicals were present at levels below the detection limit but above the levels of concern, exclusion of these chemicals from the risk assessment would underestimate the risks associated with certain ARARs. If, on the other hand, chemical concentrations are below both the detection limit and the levels of concern, their exclusion

would not significantly impact the risk estimates. Environmental parameter measurements primarily contribute to uncertainty because little verified information is available. Lack of site-specific measurements requires that estimates be made on the basis of literature values, extrapolations from regression equations, and/or best professional judgment. Modeling error can arise from the use of an inappropriate model or the use of an appropriate model with inappropriate boundary conditions. Other uncertainties can stem from a lack of validation or verification of the models.

Indoor air models were used to predict volatile organic concentrations generated through the use of contaminated groundwater. A sensitivity analysis of the shower model indicated that the total-estimated-exposure for an individual showering once a day is most sensitive to changes in temperature. Thus, the use of the model could result in an over- or underestimation of exposure.

In addition, the inability of the indoor air models to exactly duplicate the complex full-scale dispersion processes that occur in a home results in discrepancies between modeled and measured concentrations at various locations in the house. The model concentrations, like the estimated input parameters, will tend to overestimate the expected values from field measurements. Thus, the indoor air model results presented in this risk assessment should represent an upper bound for expected concentrations at receptors and are expected to yield overestimates rather than underestimates of the risks.

With respect to the exposure scenarios evaluated in this risk assessment, there are several uncertainties in determining the exposure parameters that will go into the scenario and that will ultimately be combined with toxicological information to assess risk. For example, there are a number of uncertainties regarding estimates of how often, if at all, an individual would come into contact with the chemicals of concern and the period of time over which such exposures would occur. For example, it was assumed that the ball fields would be used by individuals to play softball in the warm weather. It is not known how often or how many individuals use the fields for recreational purposes. Thus, the exposures calculated in this assessment provide a measure of potential exposures. In addition, other standard assumptions used throughout this assessment (e.g., ingestion of 2 liters of water a day, 70 kg average body weight, and 70-year lifetime), are assumed to represent upper bounds of potential exposure and have been used when site-specific data are not available. Risks for certain individuals within an exposed population will be higher or lower depending on their actual drinking water intakes, body weights, and similar factors.

Toxicological data error is also a large source of error in this risk assessment. As EPA notes in its Guidelines for Carcinogenic Risk Assessment (EPA 1986b) there are major uncertainties in extrapolating both from animals to humans and

from high to low doses. There are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species and strain differences in target site susceptibility. Human populations are variable with respect to genetic constitution, diet, occupational and home environment, activity patterns, and other cultural factors.

A particular problem is also presented by the necessity to perform risk assessments for polynuclear aromatic hydrocarbons (PAHs). PAHs occur in the environment as complex mixtures of many components with widely varying toxic potencies. Only a few components of these mixtures have been adequately characterized, and only limited information is available on potential synergistic effects of the PAH mixture. The approach adopted by EPA (1980, 1982) and used in this report as the basis for risk assessment is to divide the PAHs into two subclasses, "carcinogenic" PAHs and "noncarcinogenic" PAHs, and to apply a cancer potency factor derived from oral bioassays on benzo[a]pyrene (B[a]P) to the subclass of carcinogenic PAHs. Most evidence indicates that benzo[a]pyrene is more potent than most of the other carcinogenic PAHs and a mixture of carcinogenic PAHs (Schmahl et al. 1977, Pfeiffer 1977); therefore, this technique will probably overestimate risk. There is also a great deal of uncertainty in assessing the toxicity of a mixture of chemicals. In this assessment, the effects of exposure to each of the contaminants present in the environmental media have initially been considered separately. However, these substances occur together at the site, and individuals may be exposed to mixtures of the chemicals. Prediction of how these mixtures of toxicants will interact must be based on an understanding of the mechanisms of such interactions. The interactions of the individual components of chemical mixtures may occur during absorption, distribution, metabolism, excretion, or activity at the receptor site. Individual compounds may interact chemically, yielding a new toxic component or causing a change in the biological availability of an existing component, or may interact by causing different effects at different receptor sites. Suitable data are not currently available to rigorously characterize the effects of chemical mixtures similar to those present at the Croydon TCE site. Consequently, as recommended in EPA's Superfund Public Health Evaluation Manual (EPA 1986a) and in EPA's Guidelines for Health Risk Assessment of Chemical Mixtures (EPA 1986d), chemicals present at the Croydon TCE Site were assumed to act additively, and potential health risks were evaluated by summing excess cancer risks and calculating hazard indices for chemicals exhibiting carcinogenic and noncarcinogenic effects, respectively. This approach to assessing the risk associated with mixtures of chemicals assumes that there are no synergistic or antagonistic interactions among the chemicals considered and that all chemicals have the same toxic end points and mechanisms of action. To the extent that these assumptions are incorrect, the actual risk could be under- or overestimated.

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Where possible in this risk assessment, the potential impacts of exposures of a particular population to chemicals of concern via more than one exposure medium have been considered. For example, it can be assumed that an individual using groundwater in the home will be exposed to volatile organic compounds being released through water usage as well as through ingestion. These same individuals could be exposed to contaminated soils at the ball fields. The combined risks are discussed in the multimedia exposure subsection of the risk section. However, the additional potential effects on populations exposed to the same contaminants through a source other than those related to the Croydon TCE site and these additional exposures have not been formally considered. This may underestimate the potential impacts on future populations exposed by all of these routes.

As a result of the uncertainties described above and summarized in Table 5-31, this risk assessment should not be construed as presenting an absolute estimate of risks to human or environmental populations. Rather, it is somewhat a conservative analysis intended to indicate the potential for adverse impacts to occur.

5.9 SUMMARY AND CONCLUSIONS

This public health evaluation for the Croydon TCE Site is a baseline assessment, which evaluates potential impacts to human health and the environment in the absence of remedial action under both current- and future-use scenarios. Chemicals of potential concern were selected based on the sampling data of the environmental media and consideration of toxicity. Those selected for the groundwater pathways were divided by type of wells sampled, either residential wells or monitoring wells. These chemicals were chloroform, 4,4'-DDT (for monitoring wells only), 1,1-dichloroethane, 1,1-dichloroethene, dieldrin (for monitoring wells only), tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. The soil chemicals of potential concern were the carcinogenic polynuclear aromatic hydrocarbons (PAHs) and the polychlorinated biphenyls (PCBs). The surface water chemicals of concern were 1,1,1-trichloroethane and trichloroethene. PAHs were selected as chemicals of potential concern for the sediments. Possible exposures to human and environmental populations were considered, and the findings are summarized below.

Exposures of Human Populations

Under current land-use conditions at the Croydon TCE Site, the principal exposure pathways by which human receptors could potentially be exposed to site contaminants were

- Direct contact with surface soils by individuals using the ball fields.
- Direct contact with surface soils by certain residents.

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TABLE 5-31

UNCERTAINTIES IN THE RISK ASSESSMENT FOR THE CROYDEN TCE SITE

Assumption	Magnitude of Effect on Risk	Direction of Effect on Risk
<u>Environmental Sampling and Analysis</u>		
Sufficient samples may not have been taken to characterize the matrices being evaluated.	Moderate	May over or underestimate risk
Systematic or random errors in the chemical analyses may yield erroneous data.	Low	May over or underestimate risk
Chemical concentrations reported as "below method detection limit" are included as one-half the CLP required detection limit.	Moderate	May over or underestimate risk
The public health evaluation is based on the chemicals of concern, rather than the complete data set.	Moderate	May underestimate risk
<u>Fate and Transport Modeling</u>		
The models used to estimate indoor air concentrations assume that the releases through various household uses are similar to releases that occur during showering.	Moderate	May over or underestimate risk
<u>Toxicological Data</u>		
Some of the cancer potencies used are upper 95 percent confidence limits derived from the linearized multi-stage model.	High	May overestimate risk
Risks are assumed to be additive. Risks may not be additive because of synergistic or antagonistic actions of other chemicals.	Moderate	May over or underestimate risk

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TABLE 5-31
UNCERTAINTIES IN THE RISK ASSESSMENT FOR THE CROYDEN TCE SITE
PAGE TWO

Assumption	Magnitude of Effect on Risk	Direction of Effect on Risk
<u>Exposure Parameter Estimation</u>		
The standard assumptions regarding body weight, period of exposure, life expectancy, population characteristics, and lifestyle may not be representative for any actual exposure situation.	Moderate	May overestimate risk
The amount of media intake is assumed to be constant and representative of the exposed population.	Moderate	May overestimate risk
Exposure to contaminants remains constant over exposure period.	Moderate	May over or underestimate risk
Concentration of contaminants remains constant over exposure period.	Moderate	May over or underestimate risk
Dermal absorption of inorganic chemicals from soil is negligible.	Low	May underestimate risk
For most contaminants, all intake is assumed to come from the medium being evaluated. This does not take into account other contaminant sources such as diet, exposures occurring at locations other than the exposure point being evaluated, or other environmental media which may contribute to the intake of the chemical (i. e., relative source contributions is not accounted for).	Moderate	May underestimate risk

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- Ingestion of groundwater.
- Inhalation of and dermal contact with chemicals of potential concern in groundwater released through household uses (showering, flushing the toilet, doing laundry, running the dishwasher, general kitchen uses, and cleaning).
- Direct contact of boaters with sediments in Neshaminy Creek.
- Direct contact with sediments in Hog Run Creek by children.

Average and plausible maximum-exposure scenarios were developed for each of these pathways. The exposure point concentrations of the chemicals of potential concern were estimated for potentially exposed populations. Human health risks were assessed based on these estimates of exposure and a quantitative description of each compound's toxicity. The major conclusions of this assessment are presented in Table 5-32 and can be summarized as follows:

- Exposure of baseball players through dermal contact and incidental ingestion could result in a potential, upper bound, excess, lifetime cancer risks of 6×10^{-8} and 4×10^{-6} for the average and plausible maximum cases, respectively.
- Exposure of current residents through dermal contact and incidental ingestion could result in a potential upperbound excess lifetime cancer risk of 9×10^{-6} for the average case and 3×10^{-4} for the plausible maximum case.
- Ingestion of groundwater from residential wells could result in a potential, upper-bound, excess, lifetime cancer risk of 2×10^{-6} for the average case and 1×10^{-4} for the plausible maximum case. Under the average and plausible maximum cases, the hazard indices for noncarcinogenic exposure were less than one.
- Inhalation of volatile organics released from the groundwater during household use results in a potential, excess, upper-bound, lifetime cancer risk of 4×10^{-6} for the average case. Under conditions of the plausible maximum case, the potential, excess, upper-bound, lifetime cancer risk was 2×10^{-4} . The hazard index was less than one for both the average and plausible maximum cases.

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TABLE 5-32

SUMMARY OF RISK ASSESSMENT RESULTS FOR HUMAN EXPOSURE TO
CONTAMINANTS AT THE CROYDON TCE SITE

Exposure Pathway	Total Excess Upper Bound Lifetime Cancer Risk		Hazard Index for Noncarcinogenic Effects	
	Average Case	Plausible Maximum Case	Average Case	Plausible Maximum Case
Direct Contact and Incidental Ingestion of Soil				
Baseball Players	6×10^{-8}	4×10^{-6}	NA	NA
Current Residents	9×10^{-6}	3×10^{-4}	NA	NA
Future Residents	6×10^{-6}	9×10^{-4}	NA	NA
Ingestion of Groundwater				
Residential Wells	2×10^{-6}	1×10^{-4}	<1	<1
Monitoring Wells	7×10^{-5}	2×10^{-3}	<1	<1
Inhalation of Volatile Organic Chemicals Released Indoors from Contaminated Groundwater				
Residential Wells	4×10^{-6}	2×10^{-4}	<1	<1
Monitoring Wells	7×10^{-6}	3×10^{-3}	<1	<1
Dermal Absorption While Bathing in Contaminated Groundwater				
Residential Wells	5×10^{-6}	4×10^{-4}	<1	<1
Monitoring Wells	2×10^{-5}	5×10^{-3}	<1	>1
Direct Contact with Sediments in Neshaminy Creek	3×10^{-8}	3×10^{-6}	NA	NA
Direct Contact with Sediments in Hog Run Creek	2×10^{-8}	4×10^{-7}	NA	NA

NA = Hazard index not calculated for this exposure pathway due to lack of RFDs for the chemicals of concern in the pathway.

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- Exposure to organic compounds in the groundwater through dermal absorption and inhalation while bathing could result in a potential, upper-bound, excess, lifetime cancer risk of 5×10^{-6} and 4×10^{-4} for the average and plausible maximum cases, respectively. The hazard index was less than one for both the average and plausible maximum cases.
- Individuals exposed to sediments in Neshaminy Creek through dermal contact could have a potential, lifetime, upper-bound, excess cancer risk of 3×10^{-8} under average exposure conditions. Under plausible maximum exposure conditions, the potential, lifetime, upper-bound, excess cancer risk is 3×10^{-6} .
- Children exposed to sediments in Hog Run Creek through dermal contact could result in potential, lifetime, upperbound, excess cancer risks of 2×10^{-8} for the average case and 4×10^{-7} for the plausible maximum case.

The exposure scenarios described above would apply for possible future land-use conditions. In addition, exposure to the groundwater chemicals of potential concern in the monitoring wells were evaluated, as well as, future residential exposure to soils.

- Ingestion of groundwater from the monitoring wells could result in a potential, upper-bound, excess, lifetime cancer risk of 7×10^{-5} for the average case and 2×10^{-3} for the plausible maximum case. The hazard indices for both the average and plausible maximum exposure scenarios were less than one.
- Inhalation of volatile organic chemicals of concern released from groundwater during household activities resulted in lifetime, upper-bound, excess cancer risks of 7×10^{-6} and 3×10^{-3} for the average and plausible maximum cases, respectively. For both the average and plausible maximum cases, the hazard indices were less than one.
- Exposure to organic compounds in the groundwater through dermal absorption and inhalation while bathing could result in a potential, upper-bound, excess, lifetime cancer risk of 2×10^{-5} and 5×10^{-3} for the average and plausible maximum cases, respectively. The hazard index for the average case was less than one; for the plausible maximum case, the hazard index was greater than one.
- Direct contact with contaminated soils by future onsite residents could result in a potential, upper-bound, excess, lifetime cancer risk of 6×10^{-6} for the average case and 9×10^{-4} for the plausible maximum case.

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EXPOSURES TO WILDLIFE

The exposure to chemicals of potential concern by wildlife living in the area of the Croydon TCE Site were considered. The major conclusions of this assessment can be summarized as follows:

- Terrestrial species using the wetland and wooded areas adjacent to Neshaminy Creek and Hog Run Creek may potentially be exposed to chemicals of potential concern detected in the surface water and sediments of this area. None of these chemicals bioaccumulate, and therefore, exposure to these chemicals via the food chain is not likely.
- The observed surface water and sediment concentrations of the chemicals of potential concern do not appear to be at levels that are toxic to aquatic life.

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